

Data Wrangling 101

for BCS 206

Fall 2019

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1 Goals for next two weeks

- Thinking about workflow in R:
- Version control
- R Markdown
- Data wrangling: Turning the data into the form you need (*dplyr*)
- Data visualization:
- General principles

- How to plot in R (*ggplot*, *plotly*)

We only have a relatively short time, so we will focus on learning what tools are available and on *examples* of use (rather than an in-depth tutorial). There are great online tutorials and cheatsheets that contain further information.

2 Preliminaries

2.1 Version control

RStudio makes version control, data backup, and data sharing easy (e.g., via Github.com). To use it, download and install git on your computer. Get a free github.com or bitbucket.com account. You only have to do this once.

Then, for each project, create a new project in RStudio and link it to the remote repository (select “Create project” > “Version control”). You will have to enter a URL for the remote repository, which you get, for example, at github.com under the repository’s main page by clicking the “Clone or download button”.

For step by step instructions, see:

- Setting up RStudio for version control
- RStudio help on version control
- Reverting a file to an earlier version

2.2 Reproducibility and literate coding

R and RStudio support reproducibility oriented literate coding via Sweave and Knitr: lab books, presentations, and papers can weave/knit together data, code, and text. The document you share contains the code needed to create its outputs (figures, tables, etc.). This is achieved by combining latex or R markdown with R code (or, for that matter, code from other programming languages). For an excellent video-based introduction, see this tutorial on R markdown. *This document is R markdown compiled with RStudio’s knitr.

3 Data wrangling

The R libraries *dplyr* provide us with efficient ways to transform (‘wrangle’) our data tables. The library *magrittr* let’s us concatenate these operations in transparent and easy to read code.

3.1 An example data set

We will illustrate the use of *dplyr* with the following data from an experiment with a 2AFC task in three within-subject conditions (A, B, C), for which we have extracted correctness (1 = correct; 0 = incorrect) and reaction times (RT):

```
summary(d)
```

##	condition	trial	subject	correct
##	A:2688	Min. : 1.00	1 : 192	Min. :0.0000
##	B:2688	1st Qu.:16.75	2 : 192	1st Qu.:0.0000
##	C:2688	Median :32.50	3 : 192	Median :1.0000
##		Mean :32.50	4 : 192	Mean :0.7206
##		3rd Qu.:48.25	5 : 192	3rd Qu.:1.0000

```
##           Max.      :64.00   6           : 192   Max.      :1.0000
##                               (Other):6912
##           RT
## Min.      : 177.0
## 1st Qu.: 369.7
## Median : 525.8
## Mean      : 697.2
## 3rd Qu.: 929.1
## Max.      :2389.6
##
```

```
glimpse(d)
```

```
## Observations: 8,064
## Variables: 5
## $ condition <fct> A, A, A, A, A, A, A, A, A, A, A, A, A, A, A, A, A...
## $ trial     <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1...
## $ subject   <fct> 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 1...
## $ correct   <int> 1, 0, 0, 1, 1, 0, 1, 0, 0, 1, 0, 1, 1, 1, 0, 1, 1...
## $ RT        <dbl> 300.441, 396.845, 271.280, 503.089, 237.954, 525.879...
```

3.2 Dplyr's verbs

Dplyr has 'verbs' like filter, select, summarize, mutate, transmute, etc. to let use conduct operations on our data, and reshape the data frame into the format we need. We can use dplyr, for example, to calculate the proportion correct answers in our experiment by using *summarise*.

```
summarise(d, meanCorrect = mean(correct))
```

```
## # A tibble: 1 x 1
##   meanCorrect
##         <dbl>
## 1         0.721
```

Or just for condition A:

```
d.A = filter(d, condition == "A")
summarise(d.A, meanCorrect = mean(correct))
```

```
## # A tibble: 1 x 1
##   meanCorrect
##         <dbl>
## 1         0.603
```

3.3 Maggritr's pipes

Here we will use only of the 'pipes' magrittr provides:

- `x %>% f`: takes x and hands it to the function f on the right, as f's first argument
- `x %<>% f1 %>% f2 %>%` etc.: takes x hands it to f1, takes the output of f1 and hands it to f2, etc. And since the first pipe was `%<>%` (rather than just `%>%`), the final result will be written back into x.



Figure 1: Magritt's pipe



Figure 2: Magrittr's pipe

3.4 Putting it together: Wrangling through pipes

Remember how we got the mean proportion correct for just Condition A?

```
d.A = filter(d, condition == "A")
summarise(d.A, meanCorrect = mean(correct))
```

```
## # A tibble: 1 x 1
##   meanCorrect
##       <dbl>
## 1       0.603
```

This is inelegant and hard to read. Pipes let us make this more transparent:

```
d %>%
  filter(condition == "A") %>%
  summarise(meanCorrect = mean(correct))
```

```
## # A tibble: 1 x 1
##   meanCorrect
##       <dbl>
## 1       0.603
```

And this advantage becomes even clearer, the more operations we concatenate. For example, `group_by` is an elegant operator that tells the pipes to conduct all subsequent operations for each of the groups (and then put all the separate outcomes back together into a single data frame). So if we want the proportion correct for all groups:

```
d %>%
  group_by(condition) %>%
  summarise(meanCorrect = mean(correct))
```

```
## # A tibble: 3 x 2
```

```
##   condition meanCorrect
##   <fct>         <dbl>
## 1 A             0.603
## 2 B             0.679
## 3 C             0.880
```

4 Exercises

How can we:

- View the entire data set? (*View*)
- Calculate the by-subject averages for all three conditions? (*group_by, summarise*)
- Calculate the by-subject standard deviations around those averages? (*group_by, summarise*)
- Attach this information (the averages and SDs) to each row of the present data.frame? (*group_by, mutate*)
- Determine whether RTs were on average faster for correct, as compared to incorrect, trials?
- Add a column for log-transformed RTs to the data set?
- Remove the old column for raw RTs? (*select*)
- Sort the data by log-transformed reaction times? (*arrange*)

Say we further have an additional data frame with information about our subjects:

```
## Source: local data frame [42 x 3]
## Groups: <by row>
##
## # A tibble: 42 x 3
##   subject gender  age
##   <fct>   <chr> <dbl>
## 1 1      male    21
## 2 2      female  21
## 3 3      female  21
## 4 4      male    20
## 5 5      female  21
## 6 6      female  19
## 7 7      male    20
## 8 8      female  19
## 9 9      female  21
## 10 10     male    18
## # ... with 32 more rows
```

- How can we join the information from the two data sources together? (*left_join*)

5 Case Study I: (Rucci group)

5.1 Design

5.2 Loading data from .csv file

```
## Parsed with column specification:
```

```

## cols(
##   SMI_timestamp = col_double(),
##   Unity_timestamp = col_double(),
##   head_pos_x = col_double(),
##   head_pos_y = col_double(),
##   head_pos_z = col_double(),
##   head_rot_x = col_double(),
##   head_rot_y = col_double(),
##   head_rot_z = col_double(),
##   head_rot_w = col_double(),
##   gaze_l_x = col_double(),
##   gaze_l_y = col_double(),
##   gaze_l_z = col_double(),
##   gaze_r_x = col_double(),
##   gaze_r_y = col_double(),
##   gaze_r_z = col_double(),
##   session_idx = col_double(),
##   stimulus_deg = col_double()
## )

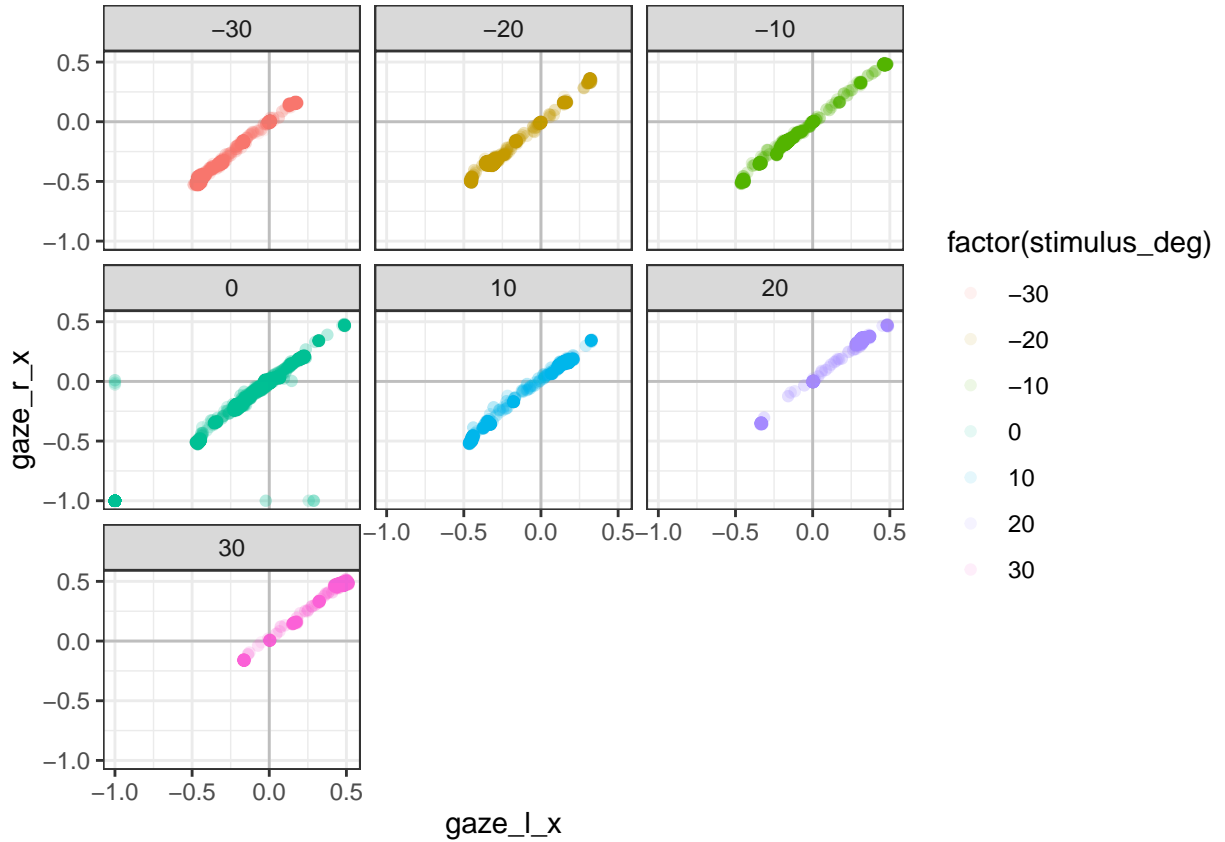
## SMI_timestamp      Unity_timestamp      head_pos_x      head_pos_y
## Min.      :0.000e+00      Min.      : 1.515      Min.      : -0.4457      Min.      : 0.9623
## 1st Qu.:4.022e+10      1st Qu.: 44.985      1st Qu.: -0.4442      1st Qu.: 0.9681
## Median :7.076e+10      Median : 75.524      Median : -0.4434      Median : 0.9685
## Mean   :7.041e+10      Mean   : 75.146      Mean   : -0.4433      Mean   : 0.9686
## 3rd Qu.:1.013e+11      3rd Qu.:106.064      3rd Qu.: -0.4427      3rd Qu.: 0.9690
## Max.    :1.319e+11      Max.    :136.625      Max.    : -0.4330      Max.    : 0.9721
##   head_pos_z      head_rot_x      head_rot_y
## Min.      : -0.09231      Min.      : -0.066826      Min.      : 0.6681
## 1st Qu.: -0.08253      1st Qu.: -0.055539      1st Qu.: 0.6983
## Median : -0.07953      Median : -0.047245      Median : 0.6990
## Mean   : -0.08053      Mean   : -0.049261      Mean   : 0.6987
## 3rd Qu.: -0.07828      3rd Qu.: -0.044043      3rd Qu.: 0.6996
## Max.    : -0.07600      Max.    : 0.007768      Max.    : 0.7042
##   head_rot_z      head_rot_w      gaze_l_x
## Min.      : -0.004449      Min.      : 0.7089      Min.      : -1.000000
## 1st Qu.: 0.039071      1st Qu.: 0.7113      1st Qu.: -0.342505
## Median : 0.039743      Median : 0.7122      Median : -0.159412
## Mean   : 0.039393      Mean   : 0.7125      Mean   : -0.126632
## 3rd Qu.: 0.040691      3rd Qu.: 0.7133      3rd Qu.: 0.007257
## Max.    : 0.044881      Max.    : 0.7440      Max.    : 0.514591
##   gaze_l_y      gaze_l_z      gaze_r_x
## Min.      : -1.000000      Min.      : -1.0000      Min.      : -1.000000
## 1st Qu.: -0.015963      1st Qu.: 0.8959      1st Qu.: -0.355706
## Median : -0.005040      Median : 0.9719      Median : -0.157496
## Mean   : -0.033892      Mean   : 0.9016      Mean   : -0.135263
## 3rd Qu.: 0.004665      3rd Qu.: 0.9947      3rd Qu.: 0.009525
## Max.    : 0.096892      Max.    : 1.0000      Max.    : 0.516798
##   gaze_r_y      gaze_r_z      session_idx      stimulus_deg
## Min.      : -1.0000000      Min.      : -1.0000      Min.      : 0.00      Min.      : -30.000
## 1st Qu.: -0.0200058      1st Qu.: 0.8845      1st Qu.: 9.00      1st Qu.: -20.000
## Median : -0.0081834      Median : 0.9708      Median : 39.00      Median : 0.000
## Mean   : -0.0360727      Mean   : 0.8959      Mean   : 41.24      Mean   : -6.309
## 3rd Qu.: 0.0000424      3rd Qu.: 0.9955      3rd Qu.: 70.00      3rd Qu.: 0.000

```

```
## Max.      : 0.1120100   Max.      : 1.0000   Max.      :96.00   Max.      : 30.000
## Joining, by = c("session_idx", "stimulus_deg")
```

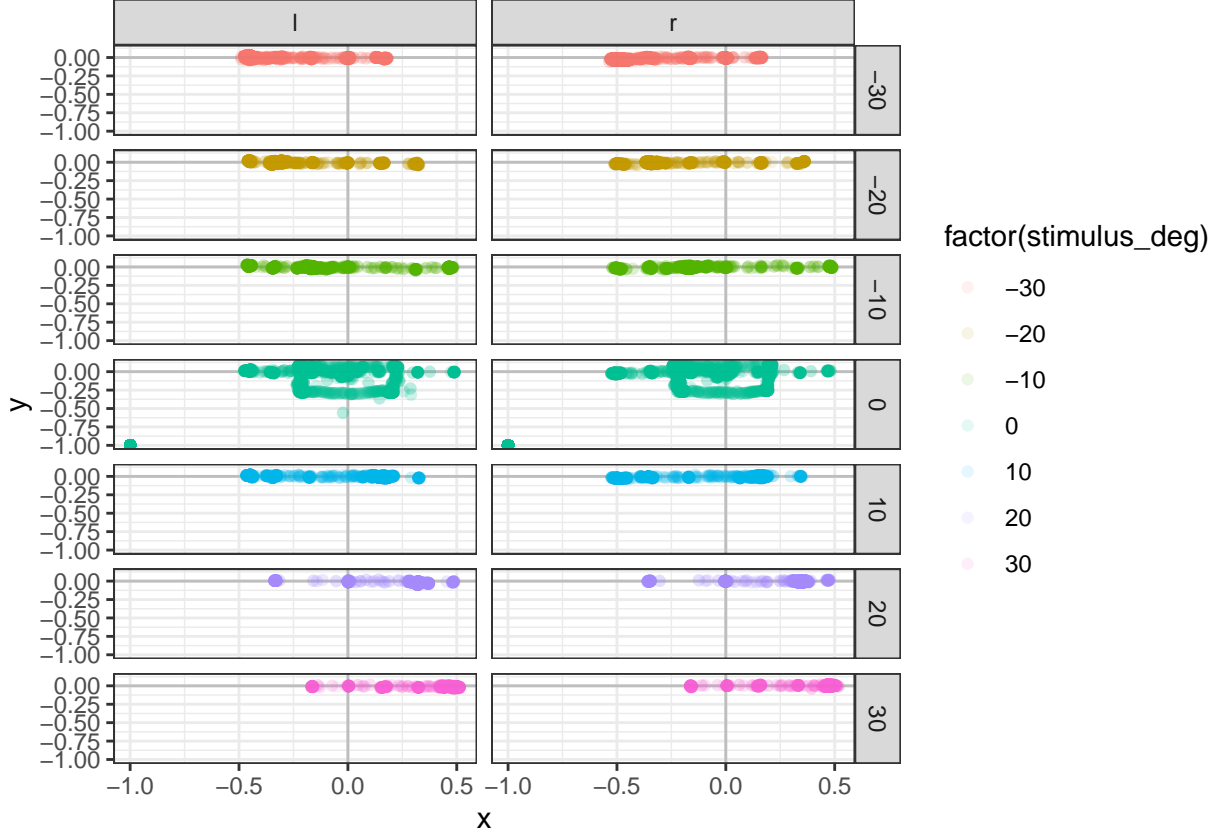
5.3 Plotting the data

5.3.1 Plotting left and right eye's x coordinate by stimulus degree



5.3.2 Plotting left and right eye's x and y coordinates by stimulus degree

For this we first need to transform that data so that we have separate rows for gaze information about the left and right eye. Then we can plot the data in a way very similar to the plot in the previous section.



6 Case Study II: visual decision-making (Haefner group)

This group seeks to replicate Herce Castañón et al. (2019).

6.1 Design

The design of the present study crossed two levels of contrast (Low = 15%, High = 60%), 3 levels of variance (0, 4, 10), and how the trials in the block were cued (L = left, R = right, N = uncued), for a total of $2 \times 3 \times 3 = 18$ within-subject conditions.

6.2 Loading data from MatLab

The data are stored in a MatLab (.mat) file. The file contains one matrix with fields: participant, experiment, stimuli and response. Within each field, there is further information. The important information seems to be in the response field. Some of the important parts include:

- responseRight: the response of the subject (0 for CCW, 1 for CW, w.r.t horizontal)
- correct: what the correct answer is (0 for CCW, 1 for CW, w.r.t horizontal)
- accuracy: whether subject got the correct answer (1) or not (0)
- reaction time: time in seconds the subject took to answer
- confidence: whether the subject was confident in their answer (1) or not (-1)
- cue: whether the cue on that trials is left (-1), right (1), or no cue (0)
- contrast: the contrast of the gabor patch on that trial
- variance: variability in the orientation of gratings of gabor patches on that trial

Fig. 2

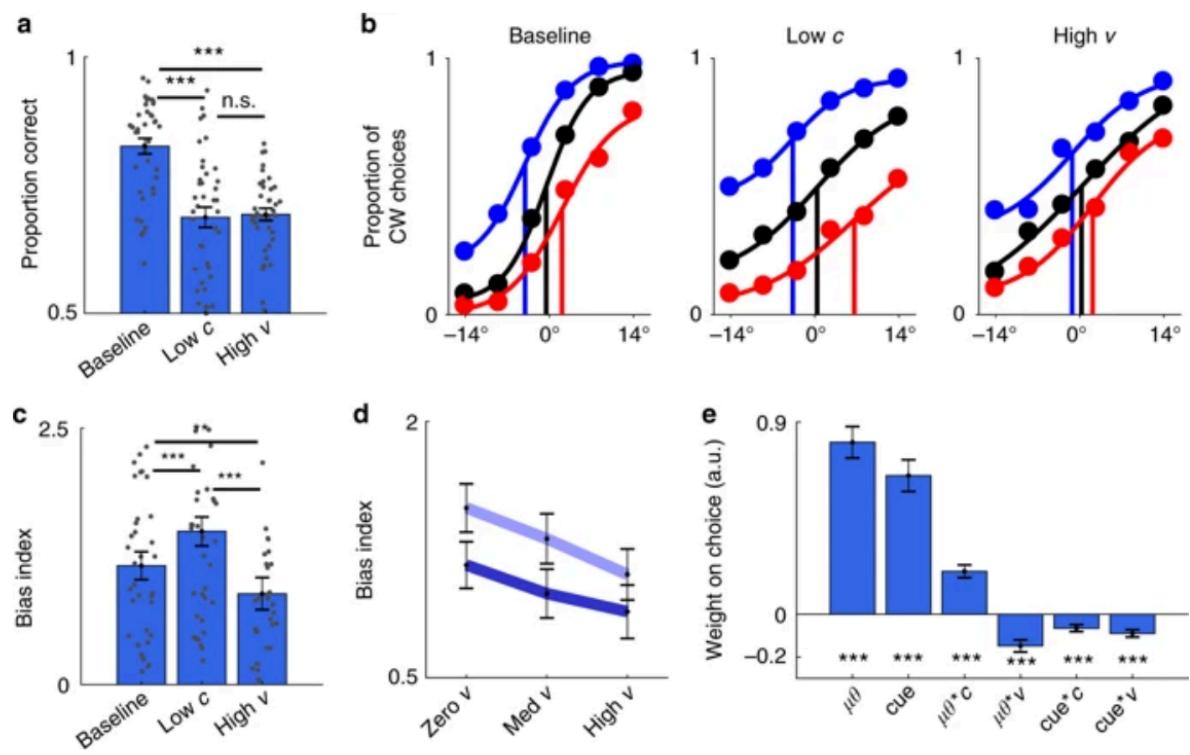


Figure 3: Figure 2 from Herce Castañón et al. (2019)

- isCuedBlock: whether a block (of trials) will have cues (1) or no cues (0)

```
# Load a matlab file and extract the "data" matrix out of it
d.haefner = readMat("./data/Haefner/uncertaintyV1-subject18-1-EarlyQuit.mat")
d.haefner = d.haefner[["data"]][, , 1][["response"]][, , 1]
d.haefner[["trueOrientations"]] <- NULL

# Look at what we've imported.
# NB: str() gives you the structure of an R object
str(d.haefner)

d.haefner %<>%
  map(.f = function(x) c(x)) %>%
  as_tibble()

# The data we have are preliminary pilot data from one of the
# experimenters, and that run did contain all trials. We omit
# all the trials with missing information.
d.haefner %<>%
  na.omit()

# Add the definition of the three conditions of interest in the
# original paper
d.haefner %<>%
  mutate(
    condition = case_when(
      variance == min(variance) & contrast == max(contrast) ~ "baseline",
      variance == max(variance) & contrast == max(contrast) ~ "high variance",
      variance == min(variance) & contrast == min(contrast) ~ "low contrast",
      T ~ ""
    )
  )
```

Now that we've imported the data into an R data frame (or *tibble*), let's have a look at it. First, we can get a general idea of the data by using `str()` (for structure) or `print()`:

```
## # A tibble: 864 x 12
##   randSeed responseRight correct accuracy reactionTime confidence
##   <dbl>         <dbl>    <dbl>    <dbl>         <dbl>         <dbl>
## 1  2.20e8           0        1        0         0.708          -1
## 2  2.20e8           1        0        0         0.609          -1
## 3  2.20e8           0        1        0         1.73           0
## 4  2.20e8           1        0        0         0.684           0
## 5  2.20e8           0        1        0         0.550          -1
## 6  2.20e8           1        1        1         0.565          -1
## 7  2.20e8           0        1        0         0.492          -1
## 8  2.20e8           0        0        1         0.994          -1
## 9  2.20e8           0        1        0         0.872           0
## 10 2.20e8           0        1        0         0.782           1
## # ... with 854 more rows, and 6 more variables: isCuedBlock <dbl>,
## #   cue <dbl>, orientationMean <dbl>, contrast <dbl>, variance <dbl>,
## #   condition <chr>
```

To instead get a summary of the data:

```
##   randSeed      responseRight      correct      accuracy
```

```

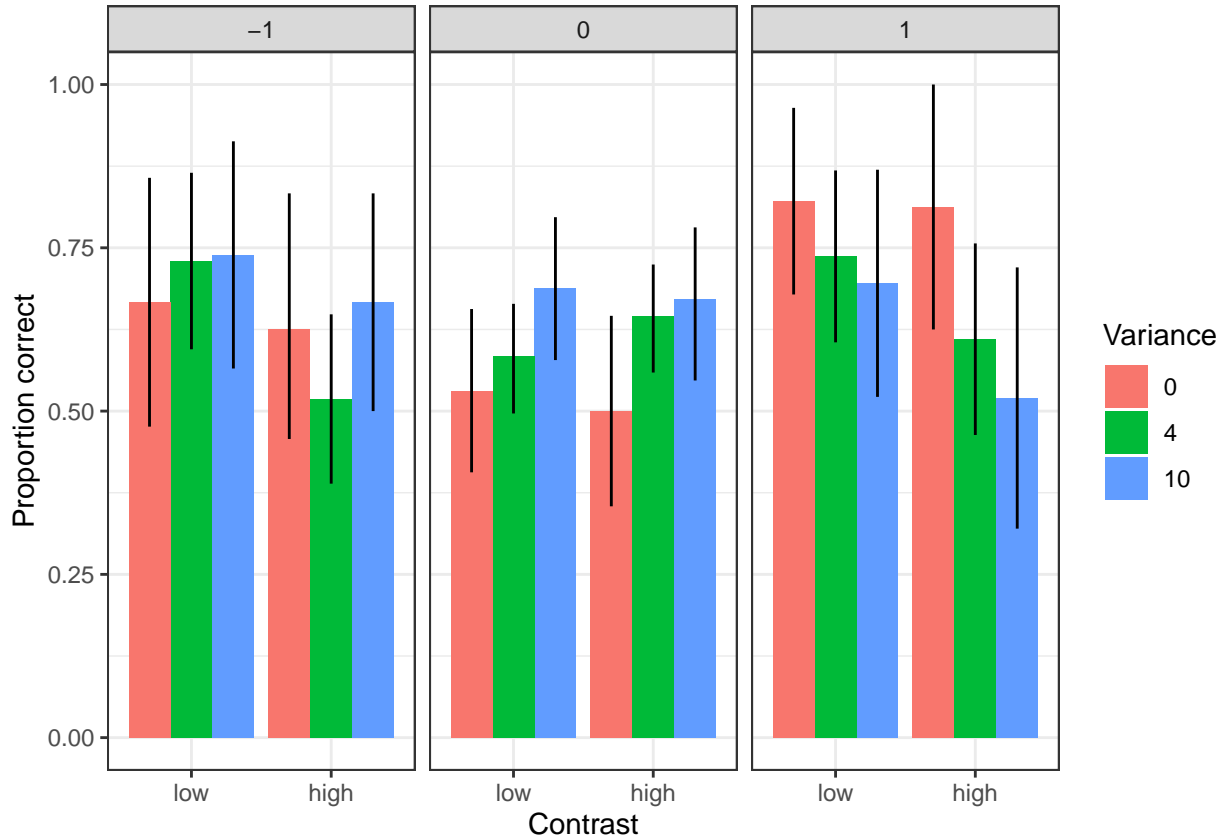
## Min. :220286057 Min. :0.000 Min. :0.0000 Min. :0.0000
## 1st Qu.:220377520 1st Qu.:0.000 1st Qu.:0.0000 1st Qu.:0.0000
## Median :220475950 Median :1.000 Median :1.0000 Median :1.0000
## Mean :220480775 Mean :0.559 Mean :0.5081 Mean :0.6319
## 3rd Qu.:220587872 3rd Qu.:1.000 3rd Qu.:1.0000 3rd Qu.:1.0000
## Max. :220674325 Max. :1.000 Max. :1.0000 Max. :1.0000
## reactionTime confidence isCuedBlock cue
## Min. :0.1983 Min. : -1.0000 Min. :0.0000 Min. : -1.00000
## 1st Qu.:0.4322 1st Qu.: -1.0000 1st Qu.:0.0000 1st Qu.: 0.00000
## Median :0.5677 Median : -1.0000 Median :0.0000 Median : 0.00000
## Mean :0.6970 Mean : -0.5289 Mean :0.4167 Mean : -0.02083
## 3rd Qu.:0.8143 3rd Qu.: 0.0000 3rd Qu.:1.0000 3rd Qu.: 0.00000
## Max. :2.9974 Max. : 1.0000 Max. :1.0000 Max. : 1.00000
## orientationMean contrast variance condition
## Min. : -26.67646 Min. :0.1500 Min. : 0.00 Length:864
## 1st Qu.: -5.95720 1st Qu.:0.1500 1st Qu.: 4.00 Class :character
## Median : 0.15682 Median :0.1500 Median : 4.00 Mode :character
## Mean : 0.08092 Mean :0.3734 Mean : 4.66
## 3rd Qu.: 5.95273 3rd Qu.:0.6000 3rd Qu.:10.00
## Max. : 25.98183 Max. :0.6000 Max. :10.00

```

6.3 Figure 2 from Herce Castañón et al.

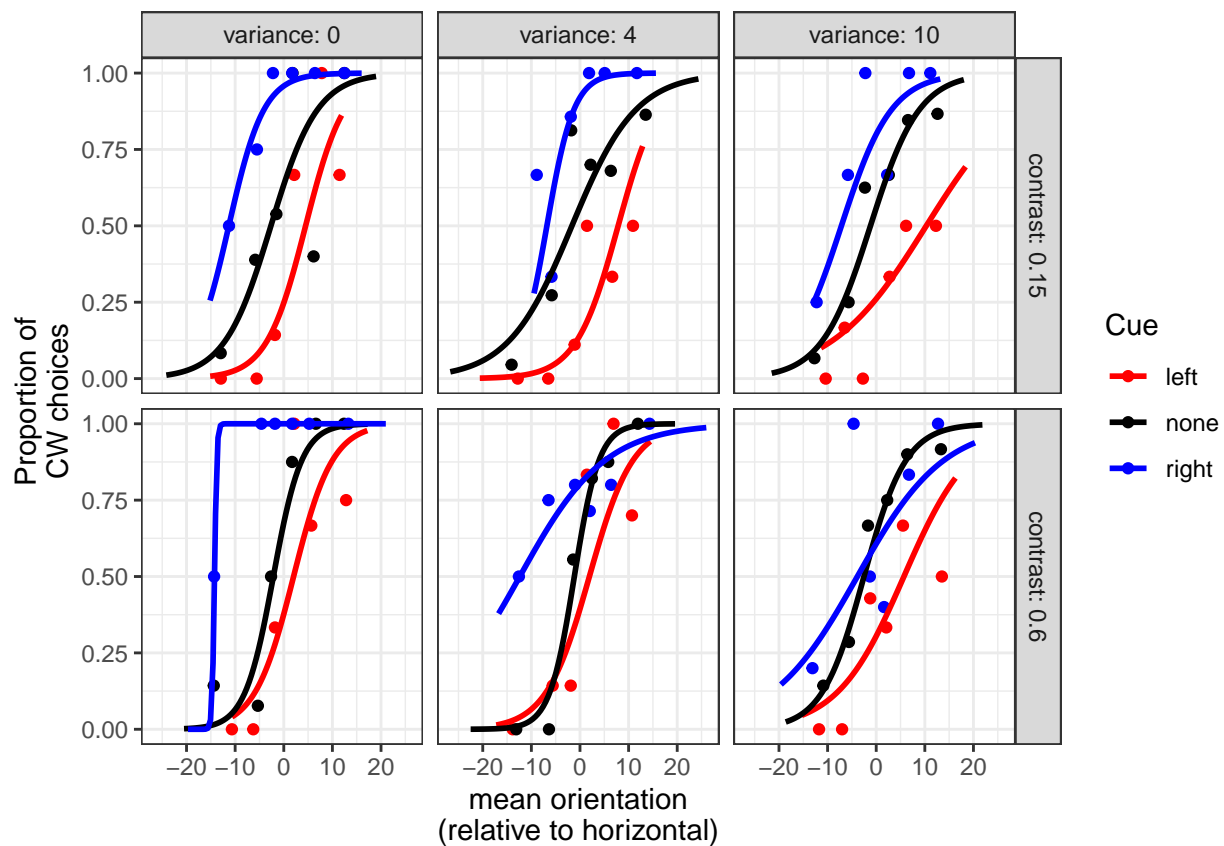
6.3.1 Panel A

We begin by plotting the proportion of correct choices for *all* conditions:

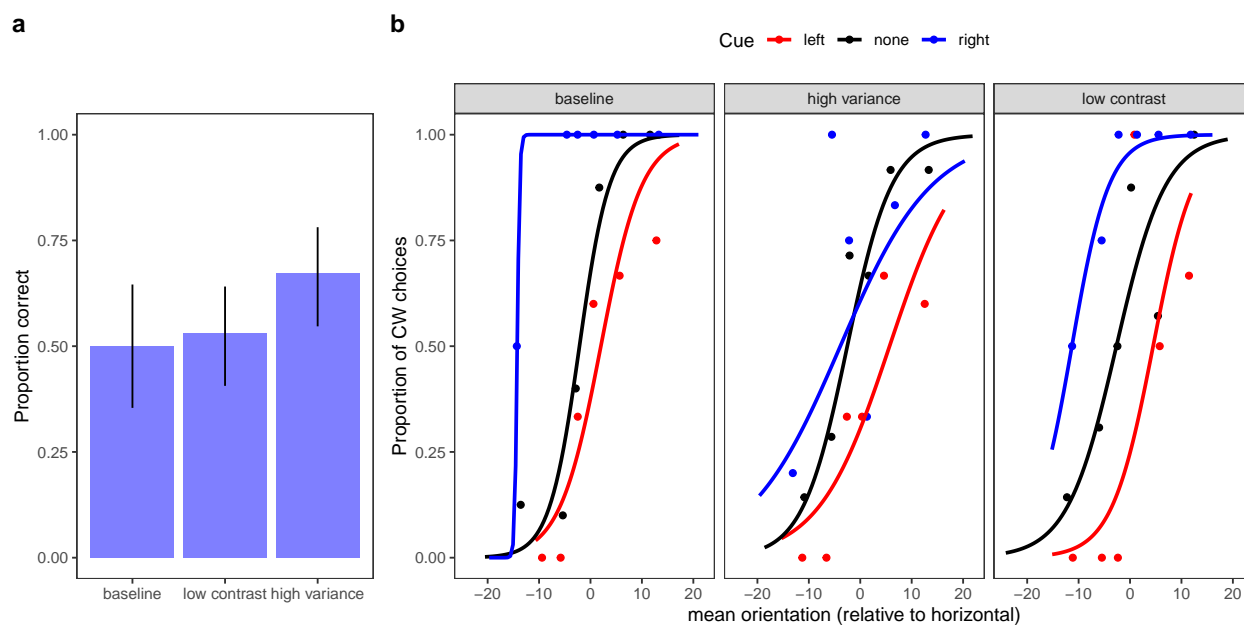


6.3.2 Panel B

We begin by plotting the proportion of CW choices for *all* conditions:



6.3.3 Panel A and B together



7 Case Study III: (Huxlin group)

7.1 Load data from Excel files

```
## Average.of.24-2          X2          X3          X4
## Length:121             Min.   :-30.000   Min.   :-29.000   Min.   :-28.000
## Class :character       1st Qu.: -18.000   1st Qu.: -3.625   1st Qu.: -2.250
## Mode  :character       Median : -2.500   Median : -2.000   Median : -1.500
##                          Mean    : -9.750   Mean    : -5.875   Mean    : -4.225
##                          3rd Qu.: -0.875   3rd Qu.: -0.875   3rd Qu.: -0.500
##                          Max.     :  0.500   Max.     :  1.000   Max.     :  1.000
##                          NA's     :111     NA's     :105     NA's     :101
##          X5             X6             X7             X8
## Min.   :-27.000   Min.   :-35.00   Min.   :-35.00   Min.   :-35.00
## 1st Qu.: -2.000   1st Qu.: -30.62   1st Qu.: -33.88   1st Qu.: -34.00
## Median : -1.500   Median : -2.00    Median : -30.75   Median : -33.50
## Mean    : -3.159   Mean    : -14.11   Mean    : -25.98   Mean    : -27.72
## 3rd Qu.:  0.375   3rd Qu.: -1.00    3rd Qu.: -25.00   3rd Qu.: -31.25
## Max.     :  3.000   Max.     :  3.00    Max.     :  9.00    Max.     : 15.00
## NA's     :99      NA's     :99      NA's     :99      NA's     :103
##          X9             X10            X11            X12
## Min.   :-34.50   Min.   :-34.50   Min.   :-33.5    Min.   :-20.000
## 1st Qu.: -33.62   1st Qu.: -33.50   1st Qu.: -21.0    1st Qu.: -7.500
## Median : -32.75   Median : -31.50   Median : -2.0     Median : -2.000
## Mean    : -26.12   Mean    : -22.67   Mean    : -6.0     Mean    : -3.333
## 3rd Qu.: -29.00   3rd Qu.: -22.00   3rd Qu.:  3.0     3rd Qu.:  3.500
## Max.     : 21.00   Max.     : 27.00   Max.     : 21.0    Max.     :  9.000
## NA's     :105     NA's     :109     NA's     :104     NA's     :109
##          X13            X14            Left.eye.24-2      X16
## Min.   :-19      Min.   :-18      Length:121      Min.   :-21.000
## 1st Qu.: -19      1st Qu.: -18      Class :character  1st Qu.: -7.000
## Median : -19      Median : -18      Mode  :character  Median : -1.000
## Mean    : -19      Mean    : -18                      Mean    : -3.118
## 3rd Qu.: -19      3rd Qu.: -18                      3rd Qu.:  1.000
## Max.     : -19      Max.     : -18                      Max.     :  9.000
## NA's     :119     NA's     :119                      NA's     :104
##          X17            X18            X19            X20
## Min.   :-15.000   Min.   :-14.000   Min.   :-13.00   Min.   :-36.00
## 1st Qu.: -6.000   1st Qu.: -2.000   1st Qu.: -3.00   1st Qu.: -33.25
## Median : -1.000   Median : -1.000   Median : -2.00   Median : -7.50
## Mean    : -3.875   Mean    : -3.167   Mean    : -2.80   Mean    : -14.70
## 3rd Qu.:  0.000   3rd Qu.: -1.000   3rd Qu.: -0.75   3rd Qu.: -0.75
## Max.     :  1.000   Max.     :  0.000   Max.     :  1.00   Max.     :  3.00
## NA's     :105     NA's     :103     NA's     :101     NA's     :101
##          X21            X22            X23            X24
## Min.   :-36.00   Min.   :-35.0    Min.   :-35.000   Min.   :-35.00
## 1st Qu.: -32.00   1st Qu.: -34.0    1st Qu.: -33.750   1st Qu.: -34.00
## Median : -3.00    Median : -32.0     Median : -9.000    Median : -33.50
## Mean    : -13.36   Mean    : -24.7     Mean    : -15.712   Mean    : -22.64
## 3rd Qu.: -1.00    3rd Qu.: -23.5     3rd Qu.: -1.125    3rd Qu.: -13.50
## Max.     :  9.00    Max.     : 15.0      Max.     : 21.000    Max.     : 27.00
## NA's     :99      NA's     :101     NA's     :95      NA's     :107
##          X25            X26            X27            X28
```

##	Min.	:-35.000	Min.	:-34.0	Min.	:-9.00	Min.	:-4
##	1st Qu.:	-27.500	1st Qu.:	-34.0	1st Qu.:	-3.50	1st Qu.:	-4
##	Median :	-3.000	Median :	-6.0	Median :	-1.25	Median :	-4
##	Mean :	-9.652	Mean :	-14.2	Mean :	-0.85	Mean :	-4
##	3rd Qu.:	-0.750	3rd Qu.:	-6.0	3rd Qu.:	1.00	3rd Qu.:	-4
##	Max. :	21.000	Max. :	9.0	Max. :	9.00	Max. :	-4
##	NA's	:98	NA's	:116	NA's	:101	NA's	:119
##	Right.eye.24-2		X30		X31		X32	
##	Length:121		Min.	:-21.000	Min.	:-15.000	Min.	:-9.000
##	Class :character		1st Qu.:	-3.000	1st Qu.:	-2.000	1st Qu.:	-3.750
##	Mode :character		Median :	-2.000	Median :	-1.250	Median :	-1.500
##			Mean :	-1.765	Mean :	-2.045	Mean :	-2.111
##			3rd Qu.:	1.000	3rd Qu.:	-1.000	3rd Qu.:	0.000
##			Max. :	9.000	Max. :	2.500	Max. :	2.000
##			NA's	:104	NA's	:99	NA's	:103
##	X33		X34		X35		X36	
##	Min.	:-34.500	Min.	:-34.00	Min.	:-35.00	Min.	:-34.00
##	1st Qu.:	-23.125	1st Qu.:	-30.00	1st Qu.:	-34.00	1st Qu.:	-32.75
##	Median :	-1.500	Median :	-2.00	Median :	-31.00	Median :	-29.00
##	Mean :	-9.467	Mean :	-11.85	Mean :	-19.48	Mean :	-19.50
##	3rd Qu.:	0.000	3rd Qu.:	1.00	3rd Qu.:	-1.00	3rd Qu.:	-4.75
##	Max. :	2.000	Max. :	3.00	Max. :	9.00	Max. :	15.00
##	NA's	:91	NA's	:101	NA's	:85	NA's	:103
##	X37		X38		X39		X40	
##	Min.	:-34.50	Min.	:-34.00	Min.	:-34.50	Min.	:-33
##	1st Qu.:	-34.00	1st Qu.:	-34.00	1st Qu.:	-33.50	1st Qu.:	-32
##	Median :	-33.50	Median :	-33.00	Median :	-32.00	Median :	8
##	Mean :	-26.31	Mean :	-18.67	Mean :	-16.52	Mean :	-8
##	3rd Qu.:	-31.75	3rd Qu.:	5.25	3rd Qu.:	5.00	3rd Qu.:	8
##	Max. :	21.00	Max. :	27.00	Max. :	21.00	Max. :	9
##	NA's	:97	NA's	:109	NA's	:98	NA's	:116
##	X41		X42		X43		X44	X45
##	Min.	:-35.00	Min.	:10	Min.	:11	Min.	:12
##	1st Qu.:	-33.00	1st Qu.:	:10	1st Qu.:	:11	1st Qu.:	:12
##	Median :	-8.00	Median :	:10	Median :	:11	Median :	:12
##	Mean :	-14.14	Mean :	:10	Mean :	:11	Mean :	:12
##	3rd Qu.:	2.50	3rd Qu.:	:10	3rd Qu.:	:11	3rd Qu.:	:12
##	Max. :	9.00	Max. :	:10	Max. :	:11	Max. :	:12
##	NA's	:99	NA's	:119	NA's	:119	NA's	:119
##	X46		X47		X48		X49	X50
##	Min.	:14	Min.	:-35.00	Min.	:16	Min.	:17
##	1st Qu.:	:14	1st Qu.:	:-33.62	1st Qu.:	:16	1st Qu.:	:17
##	Median :	:14	Median :	:-32.25	Median :	:16	Median :	:17
##	Mean :	:14	Mean :	:-21.00	Mean :	:16	Mean :	:17
##	3rd Qu.:	:14	3rd Qu.:	:-19.50	3rd Qu.:	:16	3rd Qu.:	:17
##	Max. :	:14	Max. :	:15.00	Max. :	:16	Max. :	:17
##	NA's	:119	NA's	:113	NA's	:119	NA's	:119
##	X51		X52		X53		X54	X55
##	Min.	:19	Min.	:20	Min.	:-32.50	Min.	:22
##	1st Qu.:	:19	1st Qu.:	:20	1st Qu.:	:-32.00	1st Qu.:	:22
##	Median :	:19	Median :	:20	Median :	:-31.50	Median :	:22
##	Mean :	:19	Mean :	:20	Mean :	:-14.25	Mean :	:22
##	3rd Qu.:	:19	3rd Qu.:	:20	3rd Qu.:	:8.00	3rd Qu.:	:22
##	Max. :	:19	Max. :	:20	Max. :	:21.00	Max. :	:22

```

## NA's :119 NA's :119 NA's :115 NA's :119 NA's :119
## X56 X57 X58 X59 X60
## Min. :24 Min. :25 Min. :26 Min. : -30.0 Min. :28
## 1st Qu.:24 1st Qu.:25 1st Qu.:26 1st Qu.: -30.0 1st Qu.:28
## Median :24 Median :25 Median :26 Median : -1.5 Median :28
## Mean :24 Mean :25 Mean :26 Mean : -1.5 Mean :28
## 3rd Qu.:24 3rd Qu.:25 3rd Qu.:26 3rd Qu.: 27.0 3rd Qu.:28
## Max. :24 Max. :25 Max. :26 Max. : 27.0 Max. :28
## NA's :119 NA's :119 NA's :119 NA's :117 NA's :119
## X61 X62 X63 OU X
## Min. :29 Min. :30 Min. : -21.0 Min. : NA Min. : -27
## 1st Qu.:29 1st Qu.:30 1st Qu.: -10.5 1st Qu.: NA 1st Qu.: -5
## Median :29 Median :30 Median : 0.0 Median : NA Median : 0
## Mean :29 Mean :30 Mean : 0.0 Mean :NaN Mean : 0
## 3rd Qu.:29 3rd Qu.:30 3rd Qu.: 10.5 3rd Qu.: NA 3rd Qu.: 5
## Max. :29 Max. :30 Max. : 21.0 Max. : NA Max. : 27
## NA's :119 NA's :119 NA's :78 NA's :121 NA's :1
## Y dB X68 OD
## Min. : -21 Min. : -35.00 Length:121 Min. : NA
## 1st Qu.: -5 1st Qu.: -33.50 Class :character 1st Qu.: NA
## Median : 0 Median : -4.25 Mode :character Median : NA
## Mean : 0 Mean : -16.35 Mean :NaN
## 3rd Qu.: 5 3rd Qu.: -1.00 3rd Qu.: NA
## Max. : 21 Max. : 3.00 Max. : NA
## NA's :1 NA's :1 NA's :121
## X Y dB OS
## Min. : -27.0000 Min. : -21 Min. : -34.00 Min. : NA
## 1st Qu.: -5.0000 1st Qu.: -5 1st Qu.: -33.00 1st Qu.: NA
## Median : -1.0000 Median : 0 Median : -4.00 Median : NA
## Mean : -0.7241 Mean : 0 Mean : -15.35 Mean :NaN
## 3rd Qu.: 5.0000 3rd Qu.: 5 3rd Qu.: -1.00 3rd Qu.: NA
## Max. : 21.0000 Max. : 21 Max. : 4.00 Max. : NA
## NA's :5 NA's :5 NA's :5 NA's :121
## X Y dB
## Min. : -21.0000 Min. : -21 Min. : -36.00
## 1st Qu.: -5.0000 1st Qu.: -5 1st Qu.: -34.00
## Median : 1.0000 Median : 0 Median : -27.00
## Mean : 0.7241 Mean : 0 Mean : -17.33
## 3rd Qu.: 5.0000 3rd Qu.: 5 3rd Qu.: -1.00
## Max. : 27.0000 Max. : 21 Max. : 2.50
## NA's :5 NA's :5 NA's :5

```

8 Session info

```

## - Session info -----
## setting value
## version R version 3.6.0 (2019-04-26)
## os macOS High Sierra 10.13.6
## system x86_64, darwin15.6.0
## ui X11
## language (EN)
## collate en_US.UTF-8

```

```
## ctype    en_US.UTF-8
## tz       America/New_York
## date     2019-11-05
##
## - Packages -----
## package      * version  date      lib source
## acepack      1.4.1    2016-10-29 [1] CRAN (R 3.6.0)
## assertthat   0.2.1    2019-03-21 [1] CRAN (R 3.6.0)
## backports    1.1.4    2019-04-10 [1] CRAN (R 3.6.0)
## base64enc    0.1-3    2015-07-28 [1] CRAN (R 3.6.0)
## broom        0.5.2    2019-04-07 [1] CRAN (R 3.6.0)
## callr        3.3.1    2019-07-18 [1] CRAN (R 3.6.0)
## cellranger   1.1.0    2016-07-27 [1] CRAN (R 3.6.0)
## checkmate    1.9.4    2019-07-04 [1] CRAN (R 3.6.0)
## cli          1.1.0    2019-03-19 [1] CRAN (R 3.6.0)
## cluster      2.1.0    2019-06-19 [1] CRAN (R 3.6.0)
## colorspace   1.4-1    2019-03-18 [1] CRAN (R 3.6.0)
## cowplot      * 1.0.0    2019-07-11 [1] CRAN (R 3.6.0)
## crayon       1.3.4    2017-09-16 [1] CRAN (R 3.6.0)
## data.table   1.12.2   2019-04-07 [1] CRAN (R 3.6.0)
## desc         1.2.0    2018-05-01 [1] CRAN (R 3.6.0)
## devtools     2.2.0    2019-09-07 [1] CRAN (R 3.6.0)
## digest       0.6.20   2019-07-04 [1] CRAN (R 3.6.0)
## dplyr        * 0.8.3    2019-07-04 [1] CRAN (R 3.6.0)
## DT           0.9      2019-09-17 [1] CRAN (R 3.6.0)
## ellipsis     0.2.0.1  2019-07-02 [1] CRAN (R 3.6.0)
## evaluate     0.14     2019-05-28 [1] CRAN (R 3.6.0)
## fansi        0.4.0    2018-10-05 [1] CRAN (R 3.6.0)
## forcats      * 0.4.0    2019-02-17 [1] CRAN (R 3.6.0)
## foreign      0.8-72   2019-08-02 [1] CRAN (R 3.6.0)
## Formula      1.2-3    2018-05-03 [1] CRAN (R 3.6.0)
## fs           1.3.1    2019-05-06 [1] CRAN (R 3.6.0)
## generics     0.0.2    2018-11-29 [1] CRAN (R 3.6.0)
## ggplot2      * 3.2.1    2019-08-10 [1] CRAN (R 3.6.0)
## glue         1.3.1    2019-03-12 [1] CRAN (R 3.6.0)
## gridExtra    2.3      2017-09-09 [1] CRAN (R 3.6.0)
## gtable       0.3.0    2019-03-25 [1] CRAN (R 3.6.0)
## haven        2.1.1    2019-07-04 [1] CRAN (R 3.6.0)
## Hmisc        4.2-0    2019-01-26 [1] CRAN (R 3.6.0)
## hms          0.5.1    2019-08-23 [1] CRAN (R 3.6.0)
## htmlTable    1.13.1   2019-01-07 [1] CRAN (R 3.6.0)
## htmltools    0.3.6    2017-04-28 [1] CRAN (R 3.6.0)
## htmlwidgets  1.3      2018-09-30 [1] CRAN (R 3.6.0)
## httr         1.4.1    2019-08-05 [1] CRAN (R 3.6.0)
## jsonlite     1.6      2018-12-07 [1] CRAN (R 3.6.0)
## knitr        1.25     2019-09-18 [1] CRAN (R 3.6.0)
## labeling     0.3      2014-08-23 [1] CRAN (R 3.6.0)
## lattice      0.20-38  2018-11-04 [1] CRAN (R 3.6.0)
## latticeExtra 0.6-28   2016-02-09 [1] CRAN (R 3.6.0)
## lazyeval     0.2.2    2019-03-15 [1] CRAN (R 3.6.0)
## lifecycle    0.1.0    2019-08-01 [1] CRAN (R 3.6.0)
## lubridate    1.7.4    2018-04-11 [1] CRAN (R 3.6.0)
## magrittr     * 1.5      2014-11-22 [1] CRAN (R 3.6.0)
## Matrix       1.2-17   2019-03-22 [1] CRAN (R 3.6.0)
```



```

## memoise      1.1.0      2017-04-21 [1] CRAN (R 3.6.0)
## modelr       0.1.5      2019-08-08 [1] CRAN (R 3.6.0)
## munsell      0.5.0      2018-06-12 [1] CRAN (R 3.6.0)
## nlme         3.1-141    2019-08-01 [1] CRAN (R 3.6.0)
## nnet         7.3-12     2016-02-02 [1] CRAN (R 3.6.0)
## openxlsx    * 4.1.0.1    2019-05-28 [1] CRAN (R 3.6.0)
## pillar      1.4.2      2019-06-29 [1] CRAN (R 3.6.0)
## pkgbuild     1.0.5      2019-08-26 [1] CRAN (R 3.6.0)
## pkgconfig    2.0.2      2018-08-16 [1] CRAN (R 3.6.0)
## pkgload      1.0.2      2018-10-29 [1] CRAN (R 3.6.0)
## plotly       * 4.9.0      2019-04-10 [1] CRAN (R 3.6.0)
## plyr         1.8.4      2016-06-08 [1] CRAN (R 3.6.0)
## prettyunits  1.0.2      2015-07-13 [1] CRAN (R 3.6.0)
## processx     3.4.1      2019-07-18 [1] CRAN (R 3.6.0)
## ps           1.3.0      2018-12-21 [1] CRAN (R 3.6.0)
## purrr        * 0.3.2      2019-03-15 [1] CRAN (R 3.6.0)
## R.matlab     * 3.6.2      2018-09-27 [1] CRAN (R 3.6.0)
## R.methodsS3  1.7.1      2016-02-16 [1] CRAN (R 3.6.0)
## R.oo         1.22.0     2018-04-22 [1] CRAN (R 3.6.0)
## R.utils      2.9.0      2019-06-13 [1] CRAN (R 3.6.0)
## R6           2.4.0      2019-02-14 [1] CRAN (R 3.6.0)
## RColorBrewer 1.1-2      2014-12-07 [1] CRAN (R 3.6.0)
## Rcpp         1.0.2      2019-07-25 [1] CRAN (R 3.6.0)
## readr        * 1.3.1      2018-12-21 [1] CRAN (R 3.6.0)
## readxl       1.3.1      2019-03-13 [1] CRAN (R 3.6.0)
## remotes      2.1.0      2019-06-24 [1] CRAN (R 3.6.0)
## reshape2     1.4.3      2017-12-11 [1] CRAN (R 3.6.0)
## rlang        0.4.0      2019-06-25 [1] CRAN (R 3.6.0)
## rmarkdown    1.15       2019-08-21 [1] CRAN (R 3.6.0)
## rpart        4.1-15     2019-04-12 [1] CRAN (R 3.6.0)
## rprojroot    1.3-2      2018-01-03 [1] CRAN (R 3.6.0)
## rstudioapi   0.10       2019-03-19 [1] CRAN (R 3.6.0)
## rvest        0.3.4      2019-05-15 [1] CRAN (R 3.6.0)
## scales       1.0.0      2018-08-09 [1] CRAN (R 3.6.0)
## sessioninfo  1.1.1      2018-11-05 [1] CRAN (R 3.6.0)
## stringi      1.4.3      2019-03-12 [1] CRAN (R 3.6.0)
## stringr      * 1.4.0      2019-02-10 [1] CRAN (R 3.6.0)
## survival     2.44-1.1   2019-04-01 [1] CRAN (R 3.6.0)
## testthat     2.2.1      2019-07-25 [1] CRAN (R 3.6.0)
## tibble       * 2.1.3      2019-06-06 [1] CRAN (R 3.6.0)
## tidyr        * 1.0.0      2019-09-11 [1] CRAN (R 3.6.0)
## tidyselect   0.2.5      2018-10-11 [1] CRAN (R 3.6.0)
## tidyverse    * 1.2.1      2017-11-14 [1] CRAN (R 3.6.0)
## usethis      1.5.1      2019-07-04 [1] CRAN (R 3.6.0)
## utf8         1.1.4      2018-05-24 [1] CRAN (R 3.6.0)
## vctrs        0.2.0      2019-07-05 [1] CRAN (R 3.6.0)
## viridisLite  0.3.0      2018-02-01 [1] CRAN (R 3.6.0)
## withr        2.1.2      2018-03-15 [1] CRAN (R 3.6.0)
## xfun         0.9        2019-08-21 [1] CRAN (R 3.6.0)
## xml2         1.2.2      2019-08-09 [1] CRAN (R 3.6.0)
## yaml         2.2.0      2018-07-25 [1] CRAN (R 3.6.0)
## zeallot      0.1.0      2018-01-28 [1] CRAN (R 3.6.0)
## zip          2.0.4      2019-09-01 [1] CRAN (R 3.6.0)
##

```

```
## [1] /Library/Frameworks/R.framework/Versions/3.6/Resources/library
```