Plot and examine chains: Nat. stories

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1 Preparations

```
## 'data.frame': 32341 obs. of  5 variables:
##  $ pos      : Factor w/ 32341 levels "1.1.1","1.1.word",..: 2 1 578 579 577 919 920 918 1264 1265 ..
##  $ X1       : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ word     : Factor w/ 3516 levels "-",",",":","!",..: 1575 1575 3506 3506 3506 3398 3398 3398 3172
##  $ freq     : num  1.23e+08 1.23e+08 5.78e+08 5.78e+08 5.78e+08 ...
##  $ otherfreq: logi  NA NA NA NA NA NA ...
##       pos       word item zone       freq
## 1   1.1.1         if    1    1  123141271
## 2   1.2.1        you    1    2  578117187
## 3   1.3.1       were    1    3  457504590
## 4   1.4.1         to    1    4 4223327232
## 5   1.5.1    journey    1    5    6826751
## 6   1.6.1         to    1    6 4223327232
## 7   1.7.1        the    1    7 9819942513
## 8   1.8.1      north    1    8   24140988
## 9   1.9.1         of    1    9 6162371881
## 10 1.10.1    england    1   10   21443938
## 11 1.11.1        you    1   11  578117187
## 12 1.12.1      would    1   12  319551796
## 13 1.13.1       come    1   13   69378970
## 14 1.14.1         to    1   14 4223327232
## 15 1.15.1          a    1   15 3213754375
## 16 1.16.1     valley    1   16    4303289
## 17 1.17.1       that    1   17 1746480437
## 18 1.18.1         is    1   18 1780724214
## 19 1.19.1 surrounded    1   19    4468786
## 20 1.20.1         by    1   20  877228367
## 'data.frame': 32333 obs. of  5 variables:
##  $ pos      : Factor w/ 32333 levels "1.1.1","1.1.word",..: 2 1 578 579 577 919 920 918 1264 1265 ..
##  $ X2       : int  2 2 2 2 2 2 2 2 2 2 ...
##  $ word     : Factor w/ 3511 levels "-",",",":","!",..: 1571 1571 3501 3501 3501 3393 3393 3393 3167
##  $ freq     : int  99632595 99632595 25245107 25245107 25245107 7751670 7751670 7751670 8148828 81488
##  $ otherfreq: num  2.67e+10 2.67e+10 1.23e+08 1.23e+08 1.23e+08 ...
## # A tibble: 10,256 x 5
## # Groups:   pos [10,256]
##    pos    word     item  zone    bigram
##    <chr>  <chr>   <int> <int>     <dbl>
##  1 1.1.1  if          1     1 0.00374
##  2 1.2.1  you         1     2 0.205
##  3 1.3.1  were        1     3 0.0134
##  4 1.4.1  to          1     4 0.0178
##  5 1.5.1  journey     1     5 0.0000148
##  6 1.6.1  to          1     6 0.122
##  7 1.7.1  the         1     7 0.129
##  8 1.8.1  north       1     8 0.000538
##  9 1.9.1  of          1     9 0.0107
## 10 1.10.1 england     1    10 0.000569
## # ... with 10,246 more rows
## 'data.frame': 30823 obs. of  5 variables:
##  $ pos      : Factor w/ 30823 levels "1.10.1","1.10.2",..: 555 554 880 881 879 1213 1214 1212 1541 15
##  $ X3       : int  3 3 3 3 3 3 3 3 3 3 ...
##  $ word     : Factor w/ 3351 levels "-",",",":","!",..: 3342 3342 3238 3238 3238 3020 3020 3020 1588
##  $ freq     : int  19346858 19346858 553145 553145 553145 316331 316331 316331 492 492 ...
##  $ otherfreq: int  99632595 99632595 25245107 25245107 25245107 7751670 7751670 7751670 8148828 81488
## # A tibble: 9,760 x 5
## # Groups:   pos [9,760]
##    pos    word     item  zone   trigram
##    <chr>  <chr>   <int> <int>     <dbl>
##  1 1.2.1  you         1     2 0.194
##  2 1.3.1  were        1     3 0.0219
##  3 1.4.1  to          1     4 0.0408
##  4 1.5.1  journey     1     5 0.0000604
##  5 1.6.1  to          1     6 0.279
##  6 1.7.1  the         1     7 0.253
##  7 1.8.1  north       1     8 0.000624
##  8 1.9.1  of          1     9 0.0150
##  9 1.10.1 england     1    10 0.141
## 10 1.11.1 you         1    11 0.00171
## # ... with 9,750 more rows
```

2 Predictions

Get chains and add information about words.

```
burnin <- 400

c1 <- read.csv("chains/natural_stories1/chain-0.csv")

dataf <- select(c1, starts_with("predicted_mu_rt"))

dataf <- dataf[burnin:length(dataf[, 1]), ]

c2 <- read.csv("chains/natural_stories2/chain-0.csv")

dataf.c2 <- select(c2, starts_with("predicted_mu_rt"))

dataf.c2 <- dataf.c2[burnin:length(dataf.c2[, 1]), ]

dataf <- rbind(dataf, dataf.c2)

str(dataf)

## 'data.frame': 1614 obs. of  1312 variables:
```

```
##  $ predicted_mu_rt__0   : num  307 307 307 307 307 ...
##  $ predicted_mu_rt__1   : num  339 339 339 339 339 ...
##  $ predicted_mu_rt__2   : num  350 350 350 353 353 ...
##  $ predicted_mu_rt__3   : num  307 307 307 307 307 ...
##  $ predicted_mu_rt__4   : num  316 316 316 319 319 ...
##  $ predicted_mu_rt__5   : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__6   : num  354 354 355 359 359 ...
##  $ predicted_mu_rt__7   : num  338 338 338 338 338 ...
##  $ predicted_mu_rt__8   : num  313 313 313 315 315 ...
##  $ predicted_mu_rt__9   : num  306 306 306 306 306 ...
##  $ predicted_mu_rt__10  : num  320 320 320 324 324 ...
##  $ predicted_mu_rt__11  : num  340 340 340 341 341 ...
##  $ predicted_mu_rt__12  : num  310 310 310 311 311 ...
##  $ predicted_mu_rt__13  : num  338 338 338 338 338 ...
##  $ predicted_mu_rt__14  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__15  : num  322 322 322 327 327 ...
##  $ predicted_mu_rt__16  : num  342 342 342 343 343 ...
##  $ predicted_mu_rt__17  : num  340 340 340 340 340 ...
##  $ predicted_mu_rt__18  : num  306 306 306 306 306 ...
##  $ predicted_mu_rt__19  : num  359 359 358 364 364 ...
##  $ predicted_mu_rt__20  : num  339 339 339 339 339 ...
##  $ predicted_mu_rt__21  : num  312 312 312 314 314 ...
##  $ predicted_mu_rt__22  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__23  : num  306 306 306 306 306 ...
##  $ predicted_mu_rt__24  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__25  : num  307 307 307 308 308 ...
##  $ predicted_mu_rt__26  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__27  : num  319 319 319 322 322 ...
##  $ predicted_mu_rt__28  : num  338 338 338 338 338 ...
##  $ predicted_mu_rt__29  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__30  : num  307 307 307 308 308 ...
##  $ predicted_mu_rt__31  : num  340 340 340 340 340 ...
##  $ predicted_mu_rt__32  : num  311 311 311 312 312 ...
##  $ predicted_mu_rt__33  : num  307 307 307 307 307 ...
##  $ predicted_mu_rt__34  : num  373 373 373 373 373 ...
##  $ predicted_mu_rt__35  : num  325 325 325 330 330 ...
##  $ predicted_mu_rt__36  : num  306 306 306 306 306 ...
##  $ predicted_mu_rt__37  : num  306 306 306 306 306 ...
##  $ predicted_mu_rt__38  : num  326 326 326 332 332 ...
##  $ predicted_mu_rt__39  : num  339 339 339 339 339 ...
##  $ predicted_mu_rt__40  : num  306 306 306 307 307 ...
##  $ predicted_mu_rt__41  : num  311 311 311 313 313 ...
##  $ predicted_mu_rt__42  : num  316 316 316 318 318 ...
##  $ predicted_mu_rt__43  : num  340 340 340 340 340 ...
##  $ predicted_mu_rt__44  : num  340 340 340 340 340 ...
##  $ predicted_mu_rt__45  : num  319 319 319 323 323 ...
##  $ predicted_mu_rt__46  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__47  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__48  : num  316 316 316 319 319 ...
##  $ predicted_mu_rt__49  : num  350 350 350 353 353 ...
##  $ predicted_mu_rt__50  : num  308 308 308 309 309 ...
##  $ predicted_mu_rt__51  : num  310 310 310 312 312 ...
##  $ predicted_mu_rt__52  : num  320 320 319 323 323 ...
##  $ predicted_mu_rt__53  : num  339 339 339 339 339 ...
##  $ predicted_mu_rt__54  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__55  : num  309 309 309 310 310 ...
##  $ predicted_mu_rt__56  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__57  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__58  : num  324 324 324 329 329 ...
##  $ predicted_mu_rt__59  : num  339 339 339 339 339 ...
##  $ predicted_mu_rt__60  : num  307 307 307 308 308 ...
##  $ predicted_mu_rt__61  : num  324 324 324 329 329 ...
##  $ predicted_mu_rt__62  : num  326 326 326 332 332 ...
##  $ predicted_mu_rt__63  : num  338 338 338 338 338 ...
##  $ predicted_mu_rt__64  : num  310 310 310 311 311 ...
##  $ predicted_mu_rt__65  : num  307 307 307 308 308 ...
##  $ predicted_mu_rt__66  : num  326 326 326 331 331 ...
##  $ predicted_mu_rt__67  : num  346 346 346 348 348 ...
##  $ predicted_mu_rt__68  : num  309 309 309 310 310 ...
##  $ predicted_mu_rt__69  : num  306 306 306 307 307 ...
##  $ predicted_mu_rt__70  : num  309 309 309 310 310 ...
##  $ predicted_mu_rt__71  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__72  : num  306 306 306 307 307 ...
##  $ predicted_mu_rt__73  : num  306 306 306 307 307 ...
##  $ predicted_mu_rt__74  : num  306 306 306 306 306 ...
##  $ predicted_mu_rt__75  : num  339 339 339 340 340 ...
##  $ predicted_mu_rt__76  : num  319 319 319 323 323 ...
##  $ predicted_mu_rt__77  : num  373 373 373 373 373 ...
##  $ predicted_mu_rt__78  : num  306 306 306 306 306 ...
##  $ predicted_mu_rt__79  : num  308 308 308 309 309 ...
##  $ predicted_mu_rt__80  : num  318 318 318 321 321 ...
##  $ predicted_mu_rt__81  : num  311 311 311 313 313 ...
##  $ predicted_mu_rt__82  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__83  : num  319 319 319 323 323 ...
##  $ predicted_mu_rt__84  : num  373 373 373 373 373 ...
##  $ predicted_mu_rt__85  : num  313 313 313 315 315 ...
##  $ predicted_mu_rt__86  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__87  : num  320 320 320 324 324 ...
##  $ predicted_mu_rt__88  : num  306 306 306 306 306 ...
##  $ predicted_mu_rt__89  : num  314 314 314 316 316 ...
##  $ predicted_mu_rt__90  : num  305 305 305 306 306 ...
##  $ predicted_mu_rt__91  : num  316 316 316 319 319 ...
##  $ predicted_mu_rt__92  : num  338 338 338 338 338 ...
##  $ predicted_mu_rt__93  : num  328 328 328 334 334 ...
##  $ predicted_mu_rt__94  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__95  : num  305 305 305 305 305 ...
##  $ predicted_mu_rt__96  : num  328 328 328 334 334 ...
##  $ predicted_mu_rt__97  : num  315 315 315 318 318 ...
##  $ predicted_mu_rt__98  : num  314 314 314 316 316 ...
##   [list output truncated]
```

```
ndraws <- length(dataf[, 1])
nregions <- length(dataf[1, ])

ndraws
```

```
## [1] 1614
```

```r
nregions
```

```
## [1] 1312
```

```r
wordinfo <- read.csv("additional_wordinfo.csv", sep = ",")

str(wordinfo)
```

```
## 'data.frame':	2091 obs. of  6 variables:
##  $ position   : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ zone       : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ item       : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ sentence_no: int  1 1 1 1 1 1 1 1 1 1 ...
##  $ word       : Factor w/ 608 levels ",",":","'","''",..: 258 607 576 533 275 533 510 346 352 149 ..
##  $ record_RTs : Factor w/ 2 levels "no","yes": 2 2 2 2 2 2 2 2 2 2 ...
```

```r
wordinfo <- left_join(wordinfo, freqs, by = c("zone", "item"))

wordinfo <- left_join(wordinfo, freqs2, by = c("zone", "item"))

wordinfo <- left_join(wordinfo, freqs3, by = c("zone", "item"))

head(wordinfo)
```

```
##   position zone item sentence_no  word.x record_RTs pos.x  word.y
## 1        1    1    1           1      if        yes 1.1.1      if
## 2        2    2    1           1     you        yes 1.2.1     you
## 3        3    3    1           1    were        yes 1.3.1    were
## 4        4    4    1           1      to        yes 1.4.1      to
## 5        5    5    1           1 journey        yes 1.5.1 journey
## 6        6    6    1           1      to        yes 1.6.1      to
##         freq pos.y word.x.x       bigram   pos word.y.y      trigram
## 1  123141271 1.1.1       if 3.738225e-03  <NA>     <NA>           NA
## 2  578117187 1.2.1      you 2.050093e-01 1.2.1      you 1.941820e-01
## 3  457504590 1.3.1     were 1.340848e-02 1.3.1     were 2.191098e-02
## 4 4223327232 1.4.1       to 1.781147e-02 1.4.1       to 4.080811e-02
## 5    6826751 1.5.1  journey 1.477958e-05 1.5.1  journey 6.037678e-05
## 6 4223327232 1.6.1       to 1.215130e-01 1.6.1       to 2.793861e-01
```

```r
real <- read.csv("processed_wordinfo.tsv", sep = "\t")

str(real)
```

```
## 'data.frame':	10256 obs. of  8 variables:
##  $ word       : Factor w/ 3104 levels "'Admiral","'admiral',",..: 1 2 3 4 5 6 7 8 9 10 ...
##  $ zone       : int  344 311 946 885 361 1040 716 390 842 606 ...
##  $ item       : int  9 9 6 8 9 6 1 4 2 8 ...
##  $ nItem      : int  76 78 82 70 75 79 85 88 92 73 ...
##  $ meanItemRT : num  426 420 324 352 406 ...
##  $ sdItemRT   : num  175 156 133 130 165 ...
##  $ gmeanItemRT: num  395 392 303 333 375 ...
##  $ gsdItemRT  : num  1.48 1.45 1.43 1.39 1.51 ...
```

```r
real <- select(real, word, zone, item, meanItemRT)
```

```
test_wordinfo <- subset(wordinfo, record_RTs == "yes")  # keep only wordinfo for actual words

str(test_wordinfo)

## 'data.frame': 1931 obs. of  15 variables:
##  $ position   : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ zone       : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ item       : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ sentence_no: int  1 1 1 1 1 1 1 1 1 1 ...
##  $ word.x     : Factor w/ 608 levels ",",":","'","''",..: 258 607 576 533 275 533 510 346 352 149 ..
##  $ record_RTs : Factor w/ 2 levels "no","yes": 2 2 2 2 2 2 2 2 2 2 ...
##  $ pos.x      : chr  "1.1.1" "1.2.1" "1.3.1" "1.4.1" ...
##  $ word.y     : chr  "if" "you" "were" "to" ...
##  $ freq       : num  1.23e+08 5.78e+08 4.58e+08 4.22e+09 6.83e+06 ...
##  $ pos.y      : chr  "1.1.1" "1.2.1" "1.3.1" "1.4.1" ...
##  $ word.x.x   : chr  "if" "you" "were" "to" ...
##  $ bigram     : num  3.74e-03 2.05e-01 1.34e-02 1.78e-02 1.48e-05 ...
##  $ pos        : chr  NA "1.2.1" "1.3.1" "1.4.1" ...
##  $ word.y.y   : chr  NA "you" "were" "to" ...
##  $ trigram    : num  NA 1.94e-01 2.19e-02 4.08e-02 6.04e-05 ...

test_wordinfo <- subset(test_wordinfo, sentence_no %in% c(11:57, 68:94))  # remove the first 10 sents i

test_wordinfo <- subset(test_wordinfo, position != 1)  # remove first word

str(test_wordinfo)

## 'data.frame': 1312 obs. of  15 variables:
##  $ position   : int  2 3 4 5 6 7 8 9 10 11 ...
##  $ zone       : int  294 295 296 297 298 299 300 301 302 303 ...
##  $ item       : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ sentence_no: int  11 11 11 11 11 11 11 11 11 11 ...
##  $ word.x     : Factor w/ 608 levels ",",":","'","''",..: 426 509 589 110 279 510 65 28 72 35 ...
##  $ record_RTs : Factor w/ 2 levels "no","yes": 2 2 2 2 2 2 2 2 2 2 ...
##  $ pos.x      : chr  "1.294.1" "1.295.1" "1.296.1" "1.297.1" ...
##  $ word.y     : chr  "said" "that" "whoever" "could" ...
##  $ freq       : num  1.72e+08 1.75e+09 1.32e+06 2.06e+08 7.60e+06 ...
##  $ pos.y      : chr  "1.294.1" "1.295.1" "1.296.1" "1.297.1" ...
##  $ word.x.x   : chr  "said" "that" "whoever" "could" ...
##  $ bigram     : num  1.84e-02 6.00e-02 8.99e-05 5.30e-03 7.02e-04 ...
##  $ pos        : chr  "1.294.1" "1.295.1" "1.296.1" "1.297.1" ...
##  $ word.y.y   : chr  "said" "that" "whoever" "could" ...
##  $ trigram    : num  0.018117 0.152912 0.000334 0.009856 0.003151 ...

head(test_wordinfo, n = 50)

##     position zone item sentence_no      word.x record_RTs   pos.x
## 300        2  294    1          11        said        yes 1.294.1
## 301        3  295    1          11        that        yes 1.295.1
## 302        4  296    1          11     whoever        yes 1.296.1
## 303        5  297    1          11       could        yes 1.297.1
## 304        6  298    1          11        kill        yes 1.298.1
## 305        7  299    1          11         the        yes 1.299.1
## 306        8  300    1          11        boar        yes 1.300.1
## 307        9  301    1          11         and        yes 1.301.1
## 308       10  302    1          11        bring        yes 1.302.1
## 309       11  303    1          11           as        yes 1.303.1
## 310       12  304    1          11        proof        yes 1.304.1
## 311       13  305    1          11          its        yes 1.305.1
## 312       14  306    1          11         head        yes 1.306.1
## 313       15  307    1          11           to        yes 1.307.1
## 314       16  308    1          11          the        yes 1.308.1
## 315       17  309    1          11        manor        yes 1.309.1
## 316       18  310    1          11        house        yes 1.310.1
## 317       19  311    1          11        would        yes 1.311.1
## 318       20  312    1          11           be        yes 1.312.1
## 319       21  313    1          11     rewarded        yes 1.313.1
## 320       22  314    1          11         with        yes 1.314.1
## 321       23  315    1          11         land        yes 1.315.1
## 322       24  316    1          11          and        yes 1.316.1
## 324        2  319    1          12          was        yes 1.319.1
## 325        3  320    1          12          the        yes 1.320.1
## 326        4  321    1          12       people        yes 1.321.1
## 327        5  322    1          12           of        yes 1.322.1
## 328        6  323    1          12     bradford        yes 1.323.1
## 329        7  324    1          12          and        yes 1.324.1
## 330        8  325    1          12          the        yes 1.325.1
## 331        9  326    1          12       people        yes 1.326.1
## 332       10  327    1          12          who        yes 1.327.1
## 333       11  328    1          12         knew        yes 1.328.1
## 334       12  329    1          12         them        yes 1.329.1
## 335       13  330    1          12          who        yes 1.330.1
## 336       14  331    1          12     rejoiced        yes 1.331.1
## 337       15  332    1          12           at        yes 1.332.1
## 338       16  333    1          12         this        yes 1.333.1
## 339       17  334    1          12 proclamation        yes 1.334.1
## 340       18  335    1          12          but        yes 1.335.1
## 341       19  336    1          12          one        yes 1.336.1
## 342       20  337    1          12     question        yes 1.337.1
## 343       21  338    1          12     remained        yes 1.338.1
## 345       22  339    1          12          who        yes 1.339.1
## 346       23  340    1          12        would        yes 1.340.1
## 347       24  341    1          12         kill        yes 1.341.1
## 348       25  342    1          12          the        yes 1.342.1
## 350        2  345    1          13          the        yes 1.345.1
## 351        3  346    1          13     handsome        yes 1.346.1
## 352        4  347    1          13       reward        yes 1.347.1
##           word.y       freq   pos.y     word.x.x       bigram     pos
## 300         said  171981082 1.294.1         said 1.837667e-02 1.294.1
## 301         that 1746480437 1.295.1         that 5.996172e-02 1.295.1
## 302      whoever    1317362 1.296.1      whoever 8.987046e-05 1.296.1
## 303        could  205904563 1.297.1        could 5.299986e-03 1.297.1
## 304         kill    7599359 1.298.1         kill 7.024662e-04 1.298.1
## 305          the 9819942513 1.299.1          the 9.066528e-02 1.299.1
## 306         boar     309920 1.300.1         boar 5.952581e-06 1.300.1
## 307          and 4873010095 1.301.1          and 5.775039e-02 1.301.1
## 308        bring   21687869 1.302.1        bring 2.892165e-04 1.302.1
## 309           as 1139819594 1.303.1           as 8.973680e-04 1.303.1
## 310        proof    6786238 1.304.1        proof 2.416733e-04 1.304.1
## 311          its  259806050 1.305.1          its 4.627011e-05 1.305.1
## 312         head   48252042 1.306.1         head 2.875460e-03 1.306.1
## 313           to 4223327232 1.307.1           to 2.981735e-02 1.307.1
## 314          the 9819942513 1.308.1          the 1.291914e-01 1.308.1
## 315        manor     398133 1.309.1        manor 6.630792e-06 1.309.1
## 316        house   19438505 1.310.1        house 7.086828e-02 1.310.1
## 317        would  319551796 1.311.1        would 1.946858e-03 1.311.1
## 318           be  964072174 1.312.1           be 2.122336e-01 1.312.1
## 319     rewarded    1263320 1.313.1     rewarded 2.500746e-04 1.313.1
## 320         with 1110064802 1.314.1         with 1.857867e-01 1.314.1
## 321         land   36688838 1.315.1         land 1.073091e-04 1.315.1
## 322          and 4873010095 1.316.1          and 6.337243e-02 1.316.1
## 324          was 1140172617 1.319.1          was 1.989223e-01 1.319.1
## 325          the 9819942513 1.320.1          the 5.206902e-02 1.320.1
## 326       people  149869947 1.321.1       people 1.941252e-03 1.321.1
## 327           of 6162371881 1.322.1           of 3.854132e-02 1.322.1
## 328     bradford     737565 1.323.1     bradford 7.210048e-06 1.323.1
## 329          and 4873010095 1.324.1          and 4.146753e-02 1.324.1
## 330          the 9819942513 1.325.1          the 7.519450e-02 1.325.1
## 331       people  149869947 1.326.1       people 1.941252e-03 1.326.1
## 332          who  294018466 1.327.1          who 7.445483e-02 1.327.1
## 333         knew   37182349 1.328.1         knew 4.404730e-03 1.328.1
## 334         them  240201864 1.329.1         them 4.085030e-03 1.329.1
## 335          who  294018466 1.330.1          who 9.535147e-04 1.330.1
## 336     rejoiced     346775 1.331.1     rejoiced 2.729420e-05 1.331.1
## 337           at  654432238 1.332.1           at 1.192589e-01 1.332.1
## 338         this  599554050 1.333.1         this 1.710366e-02 1.333.1
## 339 proclamation     914548 1.334.1 proclamation 3.772137e-05 1.334.1
## 340          but  422070748 1.335.1          but 1.226836e-03 1.335.1
## 341          one  398913374 1.336.1          one 7.169409e-03 1.336.1
## 342     question   44123698 1.337.1     question 5.244597e-04 1.337.1
## 343     remained   15552573 1.338.1     remained 6.293670e-04 1.338.1
## 345          who  294018466 1.339.1          who 2.089226e-04 1.339.1
## 346        would  319551796 1.340.1        would 1.712385e-02 1.340.1
## 347         kill    7599359 1.341.1         kill 9.577070e-04 1.341.1
## 348          the 9819942513 1.342.1          the 9.066528e-02 1.342.1
## 350          the 9819942513 1.345.1          the 2.355679e-01 1.345.1
## 351     handsome    2651402 1.346.1     handsome 2.160766e-05 1.346.1
## 352       reward    3549720 1.347.1       reward 1.416609e-03 1.347.1
##          word.y.y      trigram
## 300         said 1.811739e-02
## 301         that 1.529123e-01
## 302      whoever 3.335828e-04
## 303        could 9.856203e-03
## 304         kill 3.150960e-03
## 305          the 6.740827e-02
## 306         boar 4.020331e-04
## 307          and 4.754166e-02
## 308        bring 0.000000e+00
## 309           as 6.073700e-04
## 310        proof 2.569109e-03
## 311          its 7.260477e-05
## 312         head 0.000000e+00
## 313           to 3.210978e-02
## 314          the 1.840135e-01
## 315        manor 1.295780e-05
## 316        house 1.561876e-01
## 317        would 8.860535e-04
## 318           be 2.020664e-01
## 319     rewarded 3.741690e-04
## 320         with 2.214277e-01
## 321         land 4.230789e-03
## 322          and 9.392210e-02
## 324          was 2.133987e-01
## 325          the 6.906550e-02
## 326       people 3.502748e-04
## 327           of 1.445975e-01
## 328     bradford 1.990933e-05
## 329          and 5.203574e-02
## 330          the 5.832925e-02
## 331       people 2.516839e-03
## 332          who 9.393871e-02
## 333         knew 6.665208e-03
## 334         them 1.454282e-02
## 335          who 1.185060e-04
## 336     rejoiced 0.000000e+00
## 337           at 1.264798e-01
## 338         this 6.506916e-02
## 339 proclamation 1.170355e-05
## 340          but 6.190308e-04
## 341          one 0.000000e+00
## 342     question 1.136154e-03
## 343     remained 5.286453e-03
## 345          who 8.819624e-03
## 346        would 3.807237e-02
## 347         kill 2.164764e-03
## 348          the 8.011123e-02
## 350          the 2.435807e-01
## 351     handsome 0.000000e+00
## 352       reward 6.550856e-04
```

```
combined <- left_join(test_wordinfo, real, by = c("item", "zone"))

str(combined)
```

```
## 'data.frame':	1312 obs. of  17 variables:
##  $ position   : int  2 3 4 5 6 7 8 9 10 11 ...
##  $ zone       : int  294 295 296 297 298 299 300 301 302 303 ...
##  $ item       : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ sentence_no: int  11 11 11 11 11 11 11 11 11 11 ...
##  $ word.x     : Factor w/ 608 levels ",",":","'","''",..: 426 509 589 110 279 510 65 28 72 35 ...
##  $ record_RTs : Factor w/ 2 levels "no","yes": 2 2 2 2 2 2 2 2 2 2 ...
##  $ pos.x      : chr  "1.294.1" "1.295.1" "1.296.1" "1.297.1" ...
##  $ word.y     : chr  "said" "that" "whoever" "could" ...
##  $ freq       : num  1.72e+08 1.75e+09 1.32e+06 2.06e+08 7.60e+06 ...
##  $ pos.y      : chr  "1.294.1" "1.295.1" "1.296.1" "1.297.1" ...
##  $ word.x.x   : chr  "said" "that" "whoever" "could" ...
##  $ bigram     : num  1.84e-02 6.00e-02 8.99e-05 5.30e-03 7.02e-04 ...
##  $ pos        : chr  "1.294.1" "1.295.1" "1.296.1" "1.297.1" ...
##  $ word.y.y   : chr  "said" "that" "whoever" "could" ...
##  $ trigram    : num  0.018117 0.152912 0.000334 0.009856 0.003151 ...
##  $ word       : Factor w/ 3104 levels "'Admiral","'admiral',",..: 2297 2712 3024 628 1485 2717 351 16
##  $ meanItemRT : num  313 307 338 308 311 ...
```

```
# Test that we match words between wordinfo and freq dataframes: We should
# only see rows in which non-alphanumeric characters appear on word.x (-,')
subset(combined, word.x != word.y)
```

```
##      position zone item sentence_no        word.x record_RTs   pos.x
## 203        23  516    1          21  quick-witted        yes 1.516.1
## 210        30  523    1          21          what        yes 1.523.1
## 425        15  764    1          34          what        yes 1.764.1
## 449         8  800    1          40             i        yes 1.800.1
## 1048        5  707    2          85 hide-and-seek        yes 2.707.1
## 1088        5  749    2          86        peeked        yes 2.749.1
##      word.y      freq   pos.y word.x.x       bigram     pos word.y.y
## 203   quick   7462194 1.516.1    quick 9.307526e-05 1.516.1    quick
## 210       ' 836175651 1.523.1        ' 5.311628e-03 1.523.1        '
## 425       ' 836175651 1.764.1        ' 5.311628e-03 1.764.1        '
## 449       ' 836175651 1.800.1        ' 5.311628e-03 1.800.1        '
## 1048   hide   4034362 2.707.1     hide 4.999843e-04 2.707.1     hide
## 1088 peaked    445987 2.749.1   peaked 0.000000e+00 2.749.1   peaked
##           trigram          word meanItemRT
## 203  0.0011560455  quick-witted   372.9167
## 210  0.0092635573         'What   327.2588
## 425  0.0697574637         'What   335.6429
## 449  0.0849277633            'I   315.3333
## 1048 0.0009258993 hide-and-seek   363.7500
## 1088 0.0000000000        peaked   359.3556
```

```
subset(combined, word.x != word.x.x)
```

```
##      position zone item sentence_no        word.x record_RTs   pos.x
## 203        23  516    1          21  quick-witted        yes 1.516.1
## 210        30  523    1          21          what        yes 1.523.1
## 425        15  764    1          34          what        yes 1.764.1
## 449         8  800    1          40             i        yes 1.800.1
## 1048        5  707    2          85 hide-and-seek        yes 2.707.1
## 1088        5  749    2          86        peeked        yes 2.749.1
##      word.y      freq   pos.y word.x.x       bigram     pos word.y.y
## 203   quick   7462194 1.516.1    quick 9.307526e-05 1.516.1    quick
## 210       ' 836175651 1.523.1        ' 5.311628e-03 1.523.1        '
## 425       ' 836175651 1.764.1        ' 5.311628e-03 1.764.1        '
## 449       ' 836175651 1.800.1        ' 5.311628e-03 1.800.1        '
## 1048   hide   4034362 2.707.1     hide 4.999843e-04 2.707.1     hide
## 1088 peaked    445987 2.749.1   peaked 0.000000e+00 2.749.1   peaked
##           trigram          word meanItemRT
## 203  0.0011560455  quick-witted   372.9167
## 210  0.0092635573         'What   327.2588
## 425  0.0697574637         'What   335.6429
## 449  0.0849277633            'I   315.3333
## 1048 0.0009258993 hide-and-seek   363.7500
## 1088 0.0000000000        peaked   359.3556
```

```r
subset(combined, word.x != word.y.y)
```

```
##      position zone item sentence_no        word.x record_RTs   pos.x
## 203        23  516    1          21  quick-witted        yes 1.516.1
## 210        30  523    1          21          what        yes 1.523.1
## 425        15  764    1          34          what        yes 1.764.1
## 449         8  800    1          40             i        yes 1.800.1
## 1048        5  707    2          85 hide-and-seek        yes 2.707.1
## 1088        5  749    2          86        peaked        yes 2.749.1
##      word.y      freq   pos.y word.x.x       bigram     pos word.y.y
## 203   quick   7462194 1.516.1    quick 9.307526e-05 1.516.1    quick
## 210       ' 836175651 1.523.1        ' 5.311628e-03 1.523.1        '
## 425       ' 836175651 1.764.1        ' 5.311628e-03 1.764.1        '
## 449       ' 836175651 1.800.1        ' 5.311628e-03 1.800.1        '
## 1048   hide   4034362 2.707.1     hide 4.999843e-04 2.707.1     hide
## 1088 peaked    445987 2.749.1   peaked 0.000000e+00 2.749.1   peaked
##           trigram          word meanItemRT
## 203  0.0011560455  quick-witted   372.9167
## 210  0.0092635573         'What   327.2588
## 425  0.0697574637         'What   335.6429
## 449  0.0849277633            'I   315.3333
## 1048 0.0009258993 hide-and-seek   363.7500
## 1088 0.0000000000        peaked   359.3556
```

```r
head(combined)
```

```
##   position zone item sentence_no  word.x record_RTs   pos.x  word.y
## 1        2  294    1          11    said        yes 1.294.1    said
## 2        3  295    1          11    that        yes 1.295.1    that
## 3        4  296    1          11 whoever        yes 1.296.1 whoever
## 4        5  297    1          11   could        yes 1.297.1   could
## 5        6  298    1          11    kill        yes 1.298.1    kill
## 6        7  299    1          11     the        yes 1.299.1     the
##         freq   pos.y word.x.x       bigram     pos word.y.y      trigram
## 1  171981082 1.294.1     said 1.837667e-02 1.294.1     said 0.0181173936
## 2 1746480437 1.295.1     that 5.996172e-02 1.295.1     that 0.1529123104
## 3    1317362 1.296.1  whoever 8.987046e-05 1.296.1  whoever 0.0003335828
## 4  205904563 1.297.1    could 5.299986e-03 1.297.1    could 0.0098562027
## 5    7599359 1.298.1     kill 7.024662e-04 1.298.1     kill 0.0031509596
## 6 9819942513 1.299.1      the 9.066528e-02 1.299.1      the 0.0674082729
##      word meanItemRT
## 1    said   313.4706
## 2    that   306.6118
## 3 whoever   338.4706
## 4   could   308.4535
## 5    kill   310.8372
## 6     the   297.8235
```

```r
tail(combined)
```

```
##      position zone item sentence_no    word.x record_RTs   pos.x
## 1307       45  984    2          94     about        yes 2.984.1
## 1308       46  985    2          94     their        yes 2.985.1
## 1309       47  986    2          94 wonderful        yes 2.986.1
## 1310       48  987    2          94   journey        yes 2.987.1
## 1311       49  988    2          94    around        yes 2.988.1
## 1312       50  989    2          94       the        yes 2.989.1
##          word.y       freq   pos.y  word.x.x       bigram     pos
## 1307     about  265782619 2.984.1     about 3.944663e-04 2.984.1
## 1308     their  438887121 2.985.1     their 1.587209e-02 2.985.1
## 1309 wonderful    6181671 2.986.1 wonderful 6.579596e-05 2.986.1
## 1310   journey    6826751 2.987.1   journey 7.433265e-04 2.987.1
## 1311    around   66671286 2.988.1    around 2.186399e-03 2.988.1
## 1312       the 9819942513 2.989.1       the 2.829297e-01 2.989.1
##       word.y.y      trigram      word meanItemRT
## 1307     about 0.0041000859     about   314.8387
## 1308     their 0.0962324267     their   306.1720
## 1309 wonderful 0.0001680682 wonderful   320.0426
## 1310   journey 0.0011427780   journey   320.3441
## 1311    around 0.0000000000    around   375.0426
## 1312       the 0.7358970923       the   433.3913
```

Store the result into one dataframe.

```
data.all <- data.frame(Region = rep(paste("No_", str_pad(1:(nregions), width = 4,
    pad = "0"), sep = ""), each = ndraws), RT = c(dataf[1:ndraws, ], recursive = TRUE,
    use.names = FALSE), Observed = rep(combined$meanItemRT[1:(nregions)], each = ndraws),
    Word = rep(combined$word.y[1:(nregions)], each = ndraws), Item = rep(combined$item[1:(nregions)],
        each = ndraws), Sentence_no = rep(as.numeric(as.factor(combined$sentence_no)),
        each = ndraws), Position = rep(combined$position[1:(nregions)], each = ndraws),
    Freq = rep(combined$freq[1:(nregions)], each = ndraws), Bigram = rep(combined$bigram[1:(nregions)],
        each = ndraws), Trigram = rep(combined$trigram[1:(nregions)], each = ndraws))

# we remove one outlier word (Bradford) (614 ms, while mean of all other
# words below 500 ms)
data.all <- subset(data.all, Observed < 500)

str(data.all)

## 'data.frame': 2115954 obs. of  10 variables:
##  $ Region     : Factor w/ 1312 levels "No_0001","No_0002",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ RT         : num  307 307 307 307 307 ...
##  $ Observed   : num  313 313 313 313 313 ...
##  $ Word       : Factor w/ 471 levels "'","a","able",..: 330 330 330 330 330 330 330 330 330 330 ...
##  $ Item       : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ Sentence_no: num  1 1 1 1 1 1 1 1 1 1 ...
##  $ Position   : int  2 2 2 2 2 2 2 2 2 2 ...
##  $ Freq       : num  1.72e+08 1.72e+08 1.72e+08 1.72e+08 1.72e+08 ...
##  $ Bigram     : num  0.0184 0.0184 0.0184 0.0184 0.0184 ...
##  $ Trigram    : num  0.0181 0.0181 0.0181 0.0181 0.0181 ...

head(data.all)

##    Region    RT Observed Word Item Sentence_no Position      Freq
## 1 No_0001 306.6 313.4706 said    1           1        2 171981082
## 2 No_0001 306.6 313.4706 said    1           1        2 171981082
## 3 No_0001 306.7 313.4706 said    1           1        2 171981082
## 4 No_0001 307.1 313.4706 said    1           1        2 171981082
## 5 No_0001 307.1 313.4706 said    1           1        2 171981082
## 6 No_0001 307.1 313.4706 said    1           1        2 171981082
##       Bigram    Trigram
## 1 0.01837667 0.01811739
## 2 0.01837667 0.01811739
## 3 0.01837667 0.01811739
## 4 0.01837667 0.01811739
## 5 0.01837667 0.01811739
## 6 0.01837667 0.01811739
```

```
tail(data.all)
```

```
##          Region    RT Observed Word Item Sentence_no Position       Freq
## 2117563 No_1312 305.2 433.3913  the    2          70       50 9819942513
## 2117564 No_1312 305.2 433.3913  the    2          70       50 9819942513
## 2117565 No_1312 305.2 433.3913  the    2          70       50 9819942513
## 2117566 No_1312 305.2 433.3913  the    2          70       50 9819942513
## 2117567 No_1312 305.2 433.3913  the    2          70       50 9819942513
## 2117568 No_1312 305.2 433.3913  the    2          70       50 9819942513
##            Bigram   Trigram
## 2117563 0.2829297 0.7358971
## 2117564 0.2829297 0.7358971
## 2117565 0.2829297 0.7358971
## 2117566 0.2829297 0.7358971
## 2117567 0.2829297 0.7358971
## 2117568 0.2829297 0.7358971
```

```
subset(data.all, Region == "No_1311")$Word[1]  #should be word around
```

```
## [1] around
## 471 Levels: ' a able about across advance after ago all almost ... you
```

```
subset(data.all, Region == "No_1311")$Word[ndraws]  #should be word around
```

```
## [1] around
## 471 Levels: ' a able about across advance after ago all almost ... you
```

```
length(subset(data.all, Region == "No_1311")$Word)  #should be ndraws == 1614
```

```
## [1] 1614
```

We check that all predicted RTs within a sensible range (higher than 100 ms and below 1,000 ms:

```
subset(data.all, RT < 100 | RT > 1000)
```

```
##  [1] Region      RT          Observed    Word        Item
##  [6] Sentence_no Position    Freq        Bigram      Trigram
## <0 rows> (or 0-length row.names)
```

Summarise data for modeling. Below are explored models.

```
data.model <- data.all %>% group_by(Item, Region) %>% summarise(RT = mean(RT),
    Position = first(Position), Freq = first(Freq), Bigram = first(Bigram),
    Trigram = first(Trigram), Observed = first(Observed), Sentence_no = first(Sentence_no),
    Word = first(as.character(Word)))
```

```
## `summarise()` has grouped output by 'Item'. You can override using the `.groups` argument.

data.model <- data.model %>% ungroup()

data.model$Nchar <- nchar(data.model$Word)

# for each story, we calculate the absolute position of a word in that
# story, starting from one

# we use remainder of 687 (words in story 1)
data.model$Absolute_position <- as.numeric(as.factor(data.model$Region))%%687

data.model$Item <- as.factor(data.model$Item)
```

Basic check: frequency, bigram, trigram, position should be significant and negative; word length positive

```
m0 <- lm(Observed ~ 1 + log(Freq), data = subset(data.model, Bigram > 0 & Trigram >
    0))
print(summary(m0))

##
## Call:
## lm(formula = Observed ~ 1 + log(Freq), data = subset(data.model,
##     Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -48.574 -16.566  -3.471  12.873 122.936
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 347.1656     4.1902  82.851  < 2e-16 ***
## log(Freq)    -1.5956     0.2191  -7.283 6.07e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 23.19 on 1139 degrees of freedom
## Multiple R-squared:  0.0445,Adjusted R-squared:  0.04366
## F-statistic: 53.05 on 1 and 1139 DF,  p-value: 6.069e-13

m0 <- lm(Observed ~ 1 + log(Bigram), data = subset(data.model, Bigram > 0 &
    Trigram > 0))
print(summary(m0))

##
## Call:
## lm(formula = Observed ~ 1 + log(Bigram), data = subset(data.model,
##     Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -46.418 -16.692  -3.586  12.542 123.135
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 308.2690     1.4191  217.24  < 2e-16 ***
## log(Bigram)  -1.5740     0.2223   -7.08 2.51e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 23.21 on 1139 degrees of freedom
## Multiple R-squared:  0.04216,Adjusted R-squared:  0.04132
## F-statistic: 50.13 on 1 and 1139 DF,  p-value: 2.513e-12
```

```
m0 <- lm(Observed ~ 1 + log(Trigram), data = subset(data.model, Bigram > 0 &
    Trigram > 0))
print(summary(m0))
```

```
##
## Call:
## lm(formula = Observed ~ 1 + log(Trigram), data = subset(data.model,
##     Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -47.633 -16.893  -3.613  12.604 123.553
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  309.3453     1.2789 241.876  < 2e-16 ***
## log(Trigram)  -1.6063     0.2246  -7.151 1.54e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 23.2 on 1139 degrees of freedom
## Multiple R-squared:  0.04296,Adjusted R-squared:  0.04212
## F-statistic: 51.13 on 1 and 1139 DF,  p-value: 1.542e-12
```

```
m0 <- lm(Observed ~ 1 + scale(Nchar), data = subset(data.model, Bigram > 0 &
    Trigram > 0))
print(summary(m0))
```

```
##
## Call:
## lm(formula = Observed ~ 1 + scale(Nchar), data = subset(data.model,
##     Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -46.630 -15.954  -3.374  12.031 126.376
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  317.0594     0.6766 468.575   <2e-16 ***
## scale(Nchar)   6.3356     0.6769   9.359   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 22.86 on 1139 degrees of freedom
## Multiple R-squared:  0.07141,Adjusted R-squared:  0.0706
## F-statistic: 87.59 on 1 and 1139 DF,  p-value: < 2.2e-16

m0 <- lm(Observed ~ 1 + scale(Position), data = subset(data.model, Bigram >
    0 & Trigram > 0))
print(summary(m0))

##
## Call:
## lm(formula = Observed ~ 1 + scale(Position), data = subset(data.model,
##     Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -51.052 -16.747  -2.718  13.048 122.877
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)     317.0594     0.7013 452.117   <2e-16 ***
## scale(Position)  -1.2034     0.7016  -1.715   0.0866 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 23.69 on 1139 degrees of freedom
## Multiple R-squared:  0.002576,Adjusted R-squared:  0.001701
## F-statistic: 2.942 on 1 and 1139 DF,  p-value: 0.08658

m0 <- lm(Observed ~ 1 + Item * scale(Position), data = subset(data.model, Bigram >
    0 & Trigram > 0))
print(summary(m0))

##
## Call:
## lm(formula = Observed ~ 1 + Item * scale(Position), data = subset(data.model,
##     Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -49.593 -16.340  -3.378  12.556 126.971
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           312.8667     0.9716 321.998   <2e-16 ***
## Item2                   9.0598     1.4113   6.420    2e-10 ***
## scale(Position)        -1.6966     1.1249  -1.508    0.132
## Item2:scale(Position)  -0.7036     1.4427  -0.488    0.626
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 23.29 on 1137 degrees of freedom
## Multiple R-squared:  0.03786,Adjusted R-squared:  0.03532
## F-statistic: 14.91 on 3 and 1137 DF,  p-value: 1.581e-09

m0 <- lm(Observed ~ 1 + scale(Absolute_position), data = subset(data.model,
    Bigram > 0 & Trigram > 0))
print(summary(m0))
```

```
##
## Call:
## lm(formula = Observed ~ 1 + scale(Absolute_position), data = subset(data.model,
##     Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -49.607 -15.625  -2.884  11.678 132.524
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)              317.0594     0.6823 464.710  < 2e-16 ***
## scale(Absolute_position)  -5.6055     0.6826  -8.212 5.84e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 23.05 on 1139 degrees of freedom
## Multiple R-squared:  0.0559,Adjusted R-squared:  0.05507
## F-statistic: 67.44 on 1 and 1139 DF,  p-value: 5.837e-16
```

After the basic check, we consider the model with RT (this is what our model predicts).

```
# Now models with RT

m1 <- lm(Observed ~ RT - 1, data = data.model)
print(summary(m1))
```

```
##
## Call:
## lm(formula = Observed ~ RT - 1, data = data.model)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -83.576 -15.793  -0.016  17.133 139.766
##
## Coefficients:
##    Estimate Std. Error t value Pr(>|t|)
## RT 0.993428   0.002391   415.5   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 27.75 on 1310 degrees of freedom
## Multiple R-squared:  0.9925,Adjusted R-squared:  0.9925
## F-statistic: 1.727e+05 on 1 and 1310 DF,  p-value: < 2.2e-16
```

```
m1 <- lm(Observed ~ RT, data = data.model)
print(summary(m1))
```

```
##
## Call:
## lm(formula = Observed ~ RT, data = data.model)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -51.660 -17.119  -3.232  12.959 142.105
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 248.3858    12.6927  19.569  < 2e-16 ***
## RT            0.2196     0.0396   5.546 3.53e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 24.42 on 1309 degrees of freedom
## Multiple R-squared:  0.02296,Adjusted R-squared:  0.02221
## F-statistic: 30.76 on 1 and 1309 DF,  p-value: 3.534e-08
```

```
m2 <- lm(Observed ~ 1 + log(Freq) * scale(Nchar) + scale(Absolute_position) +
    RT, data = subset(data.model, Bigram > 0 & Trigram > 0))
print(summary(m2))
```

```
##
## Call:
## lm(formula = Observed ~ 1 + log(Freq) * scale(Nchar) + scale(Absolute_position) +
##     RT, data = subset(data.model, Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -49.500 -15.211  -3.033  11.343 130.528
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)              272.98254   14.77881  18.471  < 2e-16 ***
## log(Freq)                 -0.16256    0.31141  -0.522  0.60176
## scale(Nchar)              15.92324    3.83257   4.155  3.5e-05 ***
## scale(Absolute_position)  -5.78818    0.65368  -8.855  < 2e-16 ***
## RT                         0.14315    0.04032   3.551  0.00040 ***
## log(Freq):scale(Nchar)    -0.62136    0.22059  -2.817  0.00493 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.98 on 1135 degrees of freedom
## Multiple R-squared:  0.144,Adjusted R-squared:  0.1402
## F-statistic: 38.17 on 5 and 1135 DF,  p-value: < 2.2e-16
```

```
m3 <- lm(Observed ~ 1 + log(Freq) * scale(Nchar) + scale(Absolute_position) +
    log(Bigram) + RT, data = subset(data.model, Bigram > 0 & Trigram > 0))
print(summary(m3))
```

```
##
## Call:
## lm(formula = Observed ~ 1 + log(Freq) * scale(Nchar) + scale(Absolute_position) +
##     log(Bigram) + RT, data = subset(data.model, Bigram > 0 &
##     Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -49.923 -15.189  -3.034  11.535 130.804
##
```

```
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)    
## (Intercept)               264.60582   17.49033  15.129  < 2e-16 ***
## log(Freq)                   0.21544    0.52449   0.411 0.681327    
## scale(Nchar)               15.62049    3.84778   4.060 5.25e-05 ***
## scale(Absolute_position)   -5.79443    0.65378  -8.863  < 2e-16 ***
## log(Bigram)                -0.42975    0.47978  -0.896 0.370597    
## RT                          0.13966    0.04051   3.448 0.000586 ***
## log(Freq):scale(Nchar)     -0.60291    0.22156  -2.721 0.006605 ** 
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 21.99 on 1134 degrees of freedom
## Multiple R-squared:  0.1446,Adjusted R-squared:   0.14 
## F-statistic: 31.94 on 6 and 1134 DF,  p-value: < 2.2e-16
```

```
m4 <- lm(Observed ~ 1 + log(Freq) * scale(Nchar) + scale(Absolute_position) +
    log(Trigram) + RT, data = subset(data.model, Bigram > 0 & Trigram > 0))
print(summary(m4))
```

```
## 
## Call:
## lm(formula = Observed ~ 1 + log(Freq) * scale(Nchar) + scale(Absolute_position) + 
##     log(Trigram) + RT, data = subset(data.model, Bigram > 0 & 
##     Trigram > 0))
## 
## Residuals:
##     Min      1Q  Median      3Q     Max 
## -47.857 -15.262  -2.934  11.571 131.405 
## 
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)    
## (Intercept)               260.92805   16.08960  16.217  < 2e-16 ***
## log(Freq)                   0.37034    0.42047   0.881 0.378620    
## scale(Nchar)               15.18769    3.84814   3.947 8.41e-05 ***
## scale(Absolute_position)   -5.80133    0.65299  -8.884  < 2e-16 ***
## log(Trigram)               -0.68590    0.36412  -1.884 0.059860 .  
## RT                          0.13940    0.04032   3.457 0.000566 ***
## log(Freq):scale(Nchar)     -0.57893    0.22149  -2.614 0.009072 ** 
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 21.96 on 1134 degrees of freedom
## Multiple R-squared:  0.1466,Adjusted R-squared:  0.1421 
## F-statistic: 32.47 on 6 and 1134 DF,  p-value: < 2.2e-16
```

```
m5 <- lm(Observed ~ 1 + Item + log(Freq) * scale(Nchar) * scale(Absolute_position) +
    log(Trigram) + RT, data = subset(data.model, Bigram > 0 & Trigram > 0))
print(summary(m5))
```

```
## 
## Call:
## lm(formula = Observed ~ 1 + Item + log(Freq) * scale(Nchar) * 
##     scale(Absolute_position) + log(Trigram) + RT, data = subset(data.model, 
##     Bigram > 0 & Trigram > 0))
```

```
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -49.764 -14.803  -2.889  10.559 125.949
##
## Coefficients:
##                                                  Estimate Std. Error
## (Intercept)                                     259.18991   15.96620
## Item2                                             6.85067    1.30439
## log(Freq)                                         0.39436    0.41683
## scale(Nchar)                                     15.96218    3.85523
## scale(Absolute_position)                        -10.51622    6.02582
## log(Trigram)                                     -0.77738    0.36196
## RT                                                0.13136    0.04002
## log(Freq):scale(Nchar)                           -0.64553    0.22170
## log(Freq):scale(Absolute_position)                0.24322    0.31484
## scale(Nchar):scale(Absolute_position)             3.56925    3.64068
## log(Freq):scale(Nchar):scale(Absolute_position)  -0.17606    0.21015
##                                                 t value Pr(>|t|)
## (Intercept)                                      16.234  < 2e-16 ***
## Item2                                             5.252 1.80e-07 ***
## log(Freq)                                         0.946  0.34431
## scale(Nchar)                                      4.140 3.72e-05 ***
## scale(Absolute_position)                         -1.745  0.08122 .
## log(Trigram)                                     -2.148  0.03195 *
## RT                                                3.283  0.00106 **
## log(Freq):scale(Nchar)                           -2.912  0.00366 **
## log(Freq):scale(Absolute_position)                0.773  0.43997
## scale(Nchar):scale(Absolute_position)             0.980  0.32711
## log(Freq):scale(Nchar):scale(Absolute_position)  -0.838  0.40234
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.72 on 1130 degrees of freedom
## Multiple R-squared:  0.1678,Adjusted R-squared:  0.1604
## F-statistic: 22.78 on 10 and 1130 DF,  p-value: < 2.2e-16
```

```
m6 <- lm(Observed ~ 1 + Item * scale(Absolute_position) + log(Freq) * scale(Nchar) +
    log(Trigram) + RT, data = subset(data.model, Bigram > 0 & Trigram > 0))
print(summary(m6))
```

```
##
## Call:
## lm(formula = Observed ~ 1 + Item * scale(Absolute_position) +
##     log(Freq) * scale(Nchar) + log(Trigram) + RT, data = subset(data.model,
##     Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -51.274 -14.954  -2.865  10.507 130.282
##
## Coefficients:
##                                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)                     258.17336   15.88191  16.256  < 2e-16 ***
## Item2                           6.76709    1.30058   5.203 2.33e-07 ***
## scale(Absolute_position)       -4.18747    0.85641  -4.890 1.16e-06 ***
## log(Freq)                       0.38275    0.41485   0.923 0.356397
## scale(Nchar)                   15.89515    3.80266   4.180 3.14e-05 ***
## log(Trigram)                   -0.78685    0.35975  -2.187 0.028933 *
## RT                              0.13486    0.03979   3.389 0.000725 ***
## Item2:scale(Absolute_position) -3.03046    1.30353  -2.325 0.020258 *
## log(Freq):scale(Nchar)         -0.64434    0.21910  -2.941 0.003340 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.67 on 1132 degrees of freedom
## Multiple R-squared:  0.1708,Adjusted R-squared:  0.1649
## F-statistic: 29.14 on 8 and 1132 DF,  p-value: < 2.2e-16
```

```
m7 <- lm(Observed ~ 1 + Item * scale(Absolute_position) + scale(Position) +
    scale(Absolute_position):scale(Position) + log(Freq) * scale(Nchar) + log(Bigram) +
    log(Trigram) + RT, data = subset(data.model, Bigram > 0 & Trigram > 0))
print(summary(m7))
```

```
##
## Call:
## lm(formula = Observed ~ 1 + Item * scale(Absolute_position) +
##     scale(Position) + scale(Absolute_position):scale(Position) +
##     log(Freq) * scale(Nchar) + log(Bigram) + log(Trigram) + RT,
##     data = subset(data.model, Bigram > 0 & Trigram > 0))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -44.427 -14.953  -2.868  11.214 128.358
##
## Coefficients:
##                                           Estimate Std. Error t value
## (Intercept)                              258.45654   17.22758  15.002
## Item2                                      7.30177    1.32770   5.500
## scale(Absolute_position)                  -3.92831    0.86569  -4.538
## scale(Position)                           -2.02384    0.67564  -2.995
## log(Freq)                                  0.21047    0.51506   0.409
## scale(Nchar)                              16.32203    3.79208   4.304
## log(Bigram)                                0.25353    0.63193   0.401
## log(Trigram)                              -0.87681    0.48100  -1.823
## RT                                         0.14597    0.03991   3.658
## Item2:scale(Absolute_position)            -3.33487    1.34005  -2.489
## scale(Absolute_position):scale(Position)   1.64150    0.73155   2.244
## log(Freq):scale(Nchar)                    -0.68010    0.21857  -3.112
##                                          Pr(>|t|)
## (Intercept)                               < 2e-16 ***
## Item2                                    4.71e-08 ***
## scale(Absolute_position)                 6.29e-06 ***
## scale(Position)                          0.002800 **
## log(Freq)                                0.682890
## scale(Nchar)                             1.82e-05 ***
## log(Bigram)                              0.688347
## log(Trigram)                             0.068586 .
## RT                                       0.000266 ***
## Item2:scale(Absolute_position)           0.012967 *  
## scale(Absolute_position):scale(Position) 0.025033 *  
## log(Freq):scale(Nchar)                   0.001908 ** 
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 21.58 on 1129 degrees of freedom
## Multiple R-squared:  0.1796,Adjusted R-squared:  0.1716 
## F-statistic: 22.47 on 11 and 1129 DF,  p-value: < 2.2e-16
```

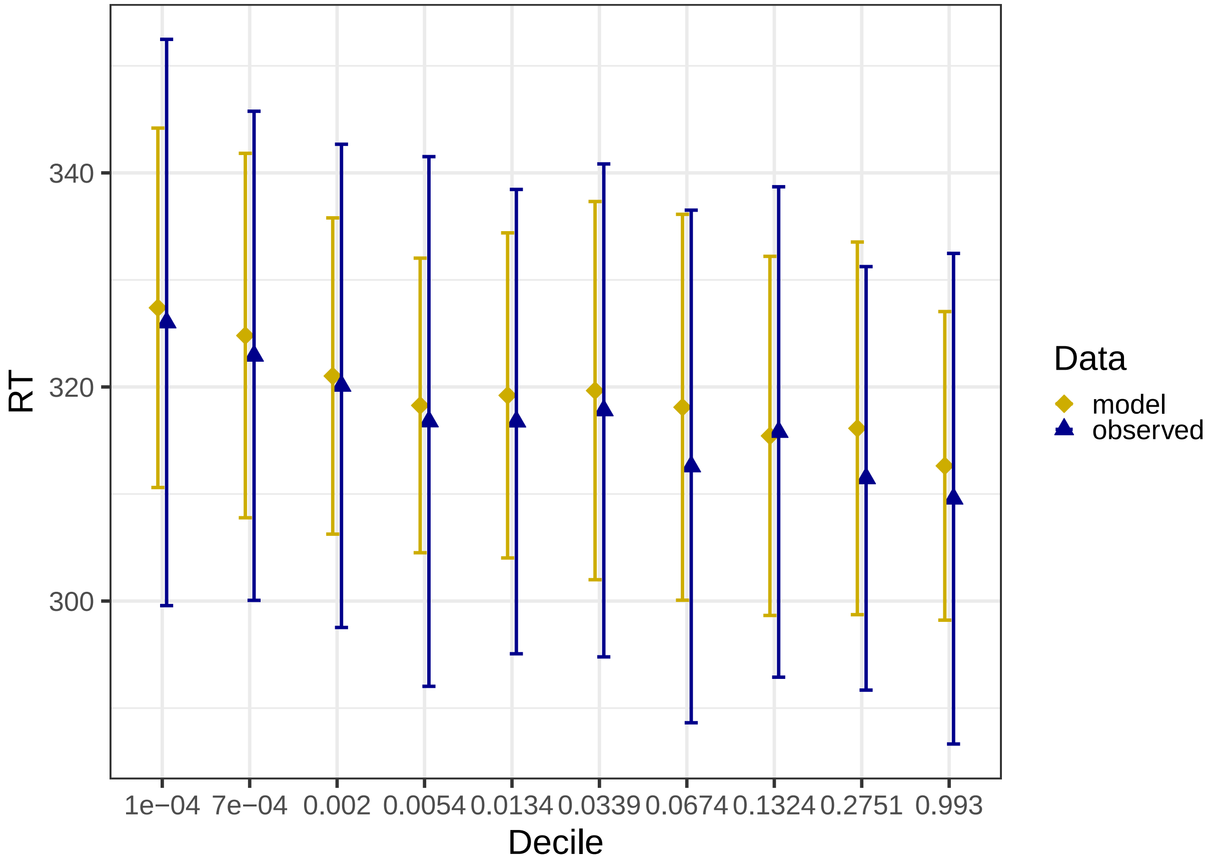
```
# extra model

m8 <- lm(Observed ~ 1 + Item + scale(Absolute_position) + scale(Position) +
    Item:scale(Absolute_position) + Item:scale(Position) + scale(Absolute_position):scale(Position) +
    log(Freq) * scale(Nchar) + log(Bigram) + log(Trigram) + RT, data = subset(data.model,
    Bigram > 0 & Trigram > 0))
print(summary(m8))
```

```
## 
## Call:
## lm(formula = Observed ~ 1 + Item + scale(Absolute_position) + 
##     scale(Position) + Item:scale(Absolute_position) + Item:scale(Position) + 
##     scale(Absolute_position):scale(Position) + log(Freq) * scale(Nchar) + 
##     log(Bigram) + log(Trigram) + RT, data = subset(data.model, 
##     Bigram > 0 & Trigram > 0))
## 
## Residuals:
##     Min      1Q  Median      3Q     Max 
## -44.357 -15.001  -2.897  11.184 128.195 
## 
## Coefficients:
##                                           Estimate Std. Error t value
## (Intercept)                              258.38149   17.24433  14.984
## Item2                                      7.30603    1.32867   5.499
## scale(Absolute_position)                  -3.93373    0.86702  -4.537
## scale(Position)                           -2.13149    1.05498  -2.020
## log(Freq)                                  0.21157    0.51535   0.411
## scale(Nchar)                              16.31885    3.79381   4.301
## log(Bigram)                                0.24837    0.63340   0.392
## log(Trigram)                              -0.87274    0.48218  -1.810
## RT                                         0.14604    0.03993   3.658
## Item2:scale(Absolute_position)            -3.34077    1.34137  -2.491
## Item2:scale(Position)                      0.17948    1.35051   0.133
## scale(Absolute_position):scale(Position)   1.63584    0.73311   2.231
## log(Freq):scale(Nchar)                    -0.67997    0.21867  -3.110
##                                          Pr(>|t|)    
## (Intercept)                               < 2e-16 ***
## Item2                                    4.73e-08 ***
## scale(Absolute_position)                 6.31e-06 ***
## scale(Position)                          0.043577 *  
## log(Freq)                                0.681493    
## scale(Nchar)                             1.84e-05 ***
## log(Bigram)                              0.695042    
## log(Trigram)                             0.070565 .
## RT                                       0.000266 ***
## Item2:scale(Absolute_position)           0.012897 *
## Item2:scale(Position)                    0.894296
## scale(Absolute_position):scale(Position) 0.025852 *
## log(Freq):scale(Nchar)                   0.001921 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.59 on 1128 degrees of freedom
## Multiple R-squared:  0.1796,Adjusted R-squared:  0.1709
## F-statistic: 20.58 on 12 and 1128 DF,  p-value: < 2.2e-16
```

3 Graphs and summaries

```
sumdata <- subset(data.model, Bigram > 0 & Trigram > 0)

cutoff <- quantile(sumdata$Trigram, seq(0, 1, 0.1))

cutoff

##           0%          10%          20%          30%          40%
## 3.325603e-07 1.442325e-04 6.922960e-04 1.969463e-03 5.388392e-03
##          50%          60%          70%          80%          90%
## 1.342504e-02 3.394567e-02 6.740827e-02 1.324086e-01 2.751196e-01
##         100%
## 9.929697e-01

str(sumdata)

## tibble [1,141 x 12] (S3: tbl_df/tbl/data.frame)
##  $ Item             : Factor w/ 2 levels "1","2": 1 1 1 1 1 1 1 1 1 1 ...
##  $ Region           : Factor w/ 1312 levels "No_0001","No_0002",..: 1 2 3 4 5 6 7 8 10 11 ...
##  $ RT               : num [1:1141] 307 339 351 307 317 ...
##  $ Position         : int [1:1141] 2 3 4 5 6 7 8 9 11 12 ...
##  $ Freq             : num [1:1141] 1.72e+08 1.75e+09 1.32e+06 2.06e+08 7.60e+06 ...
##  $ Bigram           : num [1:1141] 1.84e-02 6.00e-02 8.99e-05 5.30e-03 7.02e-04 ...
##  $ Trigram          : num [1:1141] 0.018117 0.152912 0.000334 0.009856 0.003151 ...
##  $ Observed         : num [1:1141] 313 307 338 308 311 ...
##  $ Sentence_no      : num [1:1141] 1 1 1 1 1 1 1 1 1 1 ...
##  $ Word             : chr [1:1141] "said" "that" "whoever" "could" ...
##  $ Nchar            : int [1:1141] 4 4 7 5 4 3 4 3 2 5 ...
##  $ Absolute_position: num [1:1141] 1 2 3 4 5 6 7 8 10 11 ...

sumdata$Trigramcat <- cut(sumdata$Trigram, breaks = cutoff, labels = seq(0.1,
    1, 0.1))

sumdata <- subset(sumdata, !is.na(Trigramcat))

summary.Trigram <- sumdata %>% group_by(Trigramcat) %>% summarise(Predicted = mean(RT),
    sdPredicted = sd(RT), Found = mean(Observed), sdFound = sd(Observed))
```

```
summary.Trigram$Trigramcat <- as.character(summary.Trigram$Trigramcat)

summary.Trigram$Trigramcat <- round(cutoff[2:11], 4)

summary.Trigram$Trigramcat <- as.factor(summary.Trigram$Trigramcat)

data.to.plot <- data.frame(Decile = rep(summary.Trigram$Trigramcat, 2), RT = c(summary.Trigram$Predicte
    summary.Trigram$Found), std = c(summary.Trigram$sdPredicted, summary.Trigram$sdFound),
    Data = c(rep("model", 10), rep("observed", 10)))

library(ggplot2)

library(dplyr)

g1 <- ggplot(data.to.plot, aes(Decile, RT, color = Data, fill = Data, pch = Data))
g1 <- g1 + geom_point(position = dodge, size = I(5)) + geom_errorbar(aes(ymin = RT -
    std, ymax = RT + std), position = dodge, width = 0.3, size = I(1.3)) +
    scale_shape_manual(values = 23:24) + scale_color_manual(values = c("gold3",
    "blue4")) + scale_fill_manual(values = c("gold3", "blue4")) + theme_bw(28)
```



```
ggsave("trigrams.png", width = 19, height = 12)
```

```
cutoff <- quantile(sumdata$Freq, seq(0, 1, 0.1))

cutoff
```

```
##         0%        10%        20%        30%        40%        50%
##      31747    1999559    8835068   32601982   91027817  242417228
##        60%        70%        80%        90%       100%
##  599554050 1140172617 4223327232 9819942513 9819942513
```

```
subset(sumdata, Freq >= 9.81e+09)
```

```
## # A tibble: 133 x 13
##    Item  Region    RT Position   Freq Bigram Trigram Observed Sentence_no
##    <fct> <fct>  <dbl>    <int>  <dbl>  <dbl>   <dbl>    <dbl>       <dbl>
##  1 1     No_00~  305.        7 9.82e9 0.0907  0.0674     298.           1
##  2 1     No_00~  305.       16 9.82e9 0.129   0.184      321.           1
##  3 1     No_00~  305.        3 9.82e9 0.0521  0.0691     310.           2
##  4 1     No_00~  305.        8 9.82e9 0.0752  0.0583     294.           2
##  5 1     No_00~  305.       25 9.82e9 0.0907  0.0801     295.           2
##  6 1     No_00~  305.        2 9.82e9 0.236   0.244      331.           3
##  7 1     No_00~  305.        9 9.82e9 0.0767  0.0857     355.           3
##  8 1     No_00~  305.       12 9.82e9 0.250   0.120      307.           3
##  9 1     No_00~  305.       11 9.82e9 0.274   0.934      299.           4
## 10 1     No_00~  305.       15 9.82e9 0.0142  0.0388     302            4
## # ... with 123 more rows, and 4 more variables: Word <chr>, Nchar <int>,
## #   Absolute_position <dbl>, Trigramcat <fct>
```

```
subset(sumdata, Word == "the")
```

```
## # A tibble: 133 x 13
##    Item  Region    RT Position   Freq Bigram Trigram Observed Sentence_no
##    <fct> <fct>  <dbl>    <int>  <dbl>  <dbl>   <dbl>    <dbl>       <dbl>
##  1 1     No_00~  305.        7 9.82e9 0.0907  0.0674     298.           1
##  2 1     No_00~  305.       16 9.82e9 0.129   0.184      321.           1
##  3 1     No_00~  305.        3 9.82e9 0.0521  0.0691     310.           2
##  4 1     No_00~  305.        8 9.82e9 0.0752  0.0583     294.           2
##  5 1     No_00~  305.       25 9.82e9 0.0907  0.0801     295.           2
##  6 1     No_00~  305.        2 9.82e9 0.236   0.244      331.           3
##  7 1     No_00~  305.        9 9.82e9 0.0767  0.0857     355.           3
##  8 1     No_00~  305.       12 9.82e9 0.250   0.120      307.           3
##  9 1     No_00~  305.       11 9.82e9 0.274   0.934      299.           4
## 10 1     No_00~  305.       15 9.82e9 0.0142  0.0388     302            4
## # ... with 123 more rows, and 4 more variables: Word <chr>, Nchar <int>,
## #   Absolute_position <dbl>, Trigramcat <fct>
```

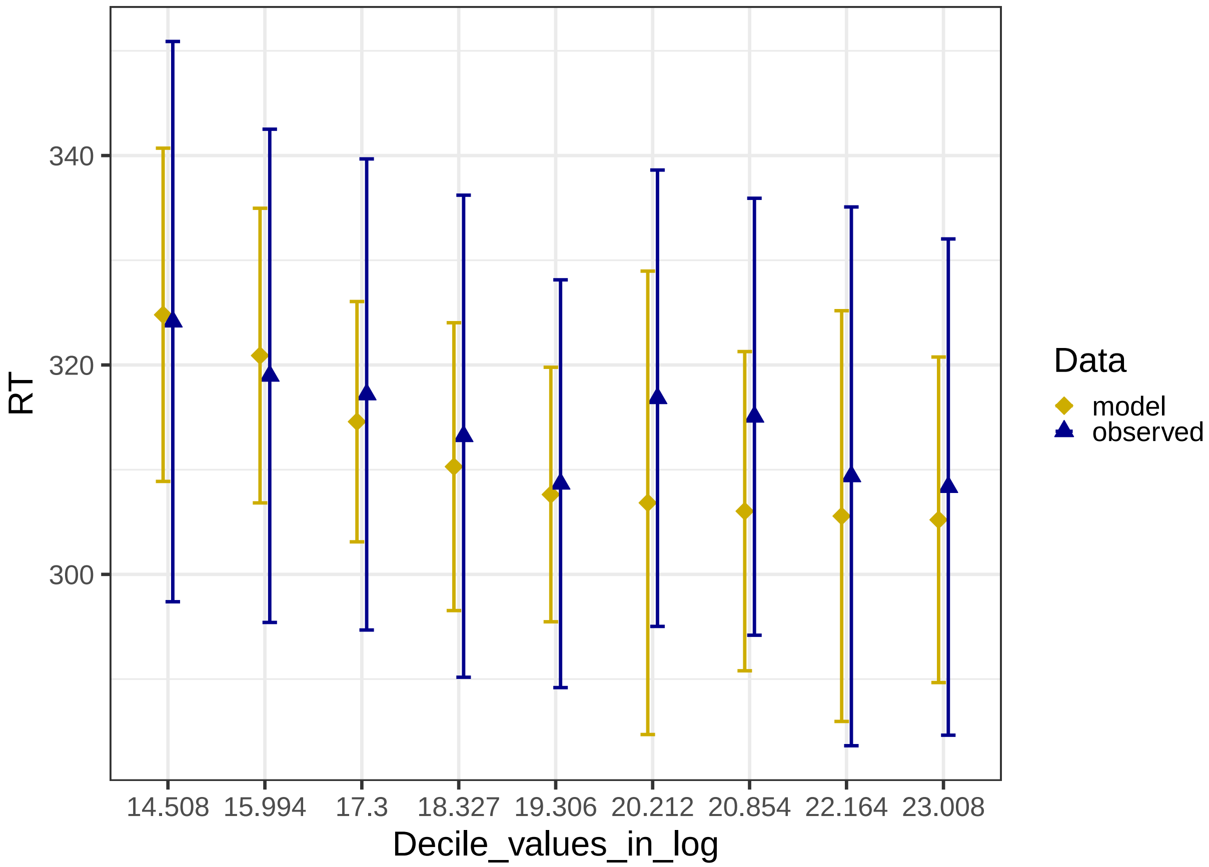
```
# cutoff[10] <- cutoff[10]-1 #we do this because just one word (the)
# occupies more than one quantile and if we did not do it, the last two
# quantiles would be identical

str(sumdata)
```

```
## tibble [1,140 x 13] (S3: tbl_df/tbl/data.frame)
##  $ Item             : Factor w/ 2 levels "1","2": 1 1 1 1 1 1 1 1 1 1 ...
##  $ Region           : Factor w/ 1312 levels "No_0001","No_0002",..: 1 2 3 4 5 6 7 8 10 11 ...
##  $ RT               : num [1:1140] 307 339 351 307 317 ...
##  $ Position         : int [1:1140] 2 3 4 5 6 7 8 9 11 12 ...
##  $ Freq             : num [1:1140] 1.72e+08 1.75e+09 1.32e+06 2.06e+08 7.60e+06 ...
##  $ Bigram           : num [1:1140] 1.84e-02 6.00e-02 8.99e-05 5.30e-03 7.02e-04 ...
##  $ Trigram          : num [1:1140] 0.018117 0.152912 0.000334 0.009856 0.003151 ...
##  $ Observed         : num [1:1140] 313 307 338 308 311 ...
##  $ Sentence_no      : num [1:1140] 1 1 1 1 1 1 1 1 1 1 ...
##  $ Word             : chr [1:1140] "said" "that" "whoever" "could" ...
##  $ Nchar            : int [1:1140] 4 4 7 5 4 3 4 3 2 5 ...
##  $ Absolute_position: num [1:1140] 1 2 3 4 5 6 7 8 10 11 ...
##  $ Trigramcat       : Factor w/ 10 levels "0.1","0.2","0.3",..: 6 9 2 5 4 7 2 7 2 4 ...
```

```
sumdata$Freqcat <- cut(sumdata$Freq, breaks = cutoff[1:10], labels = seq(0.1,
    1, 0.1)[1:9])

sumdata <- subset(sumdata, !is.na(Freqcat))

summary.Freq <- sumdata %>% group_by(Freqcat) %>% summarise(Predicted = median(RT),
    sdPredicted = sd(RT), Found = median(Observed), sdFound = sd(Observed),
    count = length(Observed))

summary.Freq
```

```
## # A tibble: 9 x 6
##   Freqcat Predicted sdPredicted Found sdFound count
## * <fct>       <dbl>       <dbl> <dbl>   <dbl> <int>
## 1 0.1          325.        15.9  324.    26.8   114
## 2 0.2          321.        14.1  319.    23.6   113
## 3 0.3          315.        11.5  317.    22.5   114
## 4 0.4          310.        13.7  313.    23.0   114
## 5 0.5          308.        12.2  309.    19.5   115
## 6 0.6          307.        22.1  317.    21.8   114
## 7 0.7          306.        15.2  315.    20.9   141
## 8 0.8          306.        19.6  309.    25.7   102
## 9 0.9          305.        15.5  308.    23.7   212
```

```
summary.Freq$Freqcat <- as.character(summary.Freq$Freqcat)

summary.Freq$Freqcat <- round(log(cutoff[2:10]), 3)

summary.Freq$Freqcat <- as.factor(summary.Freq$Freqcat)

data.to.plot <- data.frame(Decile_values_in_log = as.factor(rep(summary.Freq$Freqcat,
    2)), RT = c(summary.Freq$Predicted, summary.Freq$Found), std = c(summary.Freq$sdPredicted,
    summary.Freq$sdFound), Data = c(rep("model", 9), rep("observed", 9)))

library(ggplot2)

library(dplyr)

g1 <- ggplot(data.to.plot, aes(Decile_values_in_log, RT, color = Data, fill = Data,
    pch = Data))
g1 <- g1 + geom_point(position = dodge, size = I(5)) + geom_errorbar(aes(ymin = RT -
    std, ymax = RT + std), position = dodge, width = 0.3, size = I(1.3)) +
    scale_shape_manual(values = 23:24) + scale_color_manual(values = c("gold3",
    "blue4")) + scale_fill_manual(values = c("gold3", "blue4")) + theme_bw(28)
```



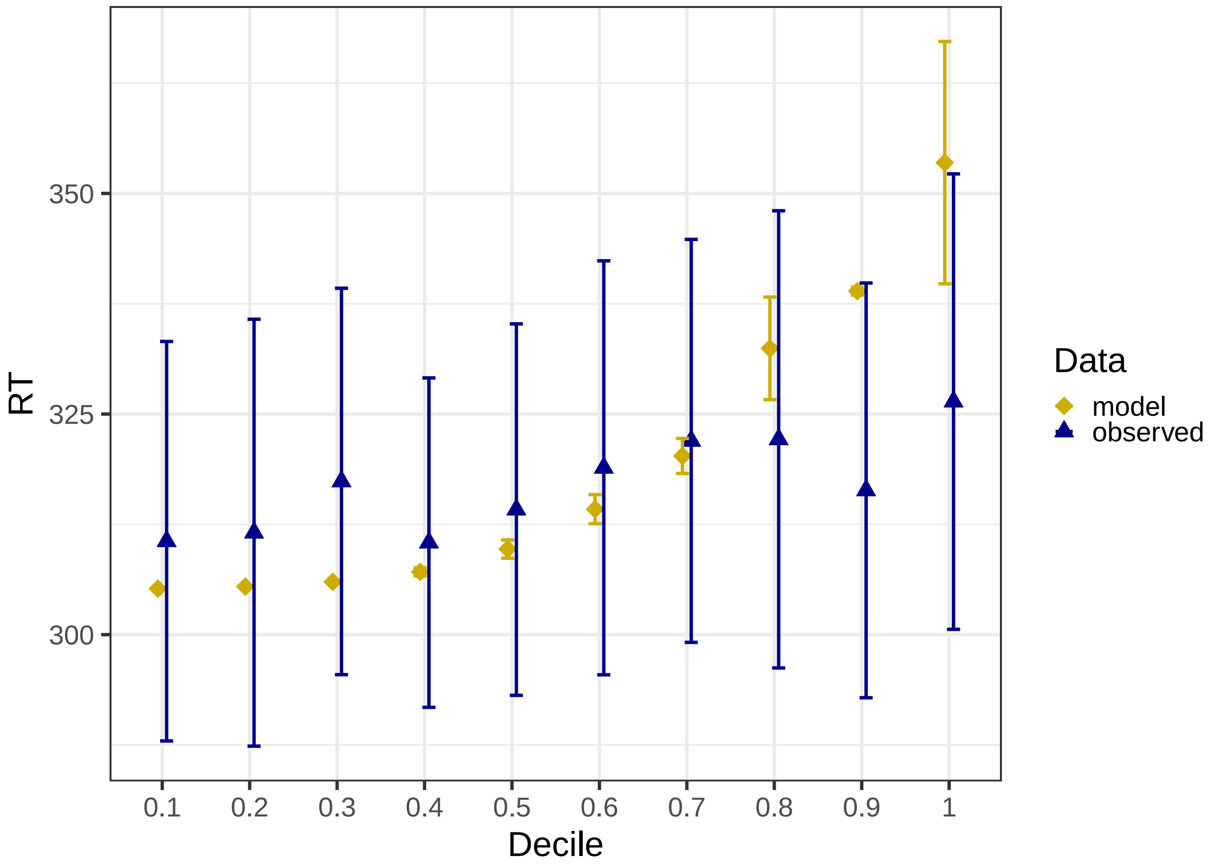
```
ggsave("freqs.png", width = 19, height = 12)
```

```
cutoff <- quantile(sumdata$RT, seq(0, 1, 0.1))

cutoff

##       0%      10%      20%      30%      40%      50%      60%      70%
## 305.2119 305.2129 305.7162 306.1664 307.9639 311.6690 316.8998 323.8358
##      80%      90%     100%
## 338.3626 339.8425 397.1125

sumdata$RTcat <- cut(sumdata$RT, breaks = cutoff, labels = seq(0.1, 1, 0.1))

sumdata <- subset(sumdata, !is.na(RTcat))

summary.RT <- sumdata %>% group_by(RTcat) %>% summarise(Predicted = mean(RT),
    sdPredicted = sd(RT), Found = mean(Observed), sdFound = sd(Observed))

summary.RT

## # A tibble: 10 x 5
##    RTcat Predicted sdPredicted Found sdFound
##  * <fct>     <dbl>       <dbl> <dbl>   <dbl>
##  1 0.1        305.    0.000310  311.    22.6
##  2 0.2         305.    0.127     312.    24.2
##  3 0.3         306.    0.159     317.    21.9
##  4 0.4         307.    0.464     310.    18.7
##  5 0.5         310.    1.03      314.    21.1
##  6 0.6         314.    1.65      319.    23.5
##  7 0.7         320.    1.98      322.    22.8
##  8 0.8         332.    5.81      322.    25.9
##  9 0.9         339.    0.442     316.    23.5
## 10 1           353.   13.7       326.    25.8
```

```
cor.test(summary.RT$Predicted, summary.RT$Found)
```

```
##
##  Pearson's product-moment correlation
##
## data:  summary.RT$Predicted and summary.RT$Found
## t = 3.4725, df = 8, p-value = 0.008412
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.2847095 0.9440889
## sample estimates:
##       cor
## 0.7753467
```

```
data.to.plot <- data.frame(Decile = rep(summary.RT$RTcat, 2), RT = c(summary.RT$Predicted,
    summary.RT$Found), std = c(summary.RT$sdPredicted, summary.RT$sdFound),
    Data = c(rep("model", 10), rep("observed", 10)))

library(ggplot2)

library(dplyr)

g1 <- ggplot(data.to.plot, aes(Decile, RT, color = Data, fill = Data, pch = Data))
g1 <- g1 + geom_point(position = dodge, size = I(5)) + geom_errorbar(aes(ymin = RT -
    std, ymax = RT + std), position = dodge, width = 0.3, size = I(1.3)) +
    scale_shape_manual(values = 23:24) + scale_color_manual(values = c("gold3",
    "blue4")) + scale_fill_manual(values = c("gold3", "blue4")) + theme_bw(28)
```



```
cutoff <- quantile(sumdata$Observed, seq(0, 1, 0.1))

sumdata$Observedcat <- cut(sumdata$Observed, breaks = cutoff, labels = seq(0.1,
    1, 0.1))

sumdata <- subset(sumdata, !is.na(Observedcat))

summary.Observed <- sumdata %>% group_by(Observedcat) %>% summarise(Predicted = mean(RT),
    sdPredicted = sd(RT), Found = mean(Observed), sdFound = sd(Observed))

summary.Observed

## # A tibble: 10 x 5
##    Observedcat Predicted sdPredicted Found sdFound
##  * <fct>           <dbl>       <dbl> <dbl>   <dbl>
##  1 0.1              316.        14.3  284.    5.01
##  2 0.2              316.        15.1  294.    2.22
##  3 0.3              318.        16.3  300.    1.98
##  4 0.4              316.        16.0  307.    1.44
##  5 0.5              320.        16.9  311.    1.60
##  6 0.6              321.        17.5  317.    1.41
##  7 0.7              318.        17.3  322.    1.84
##  8 0.8              320.        15.1  330.    2.65
##  9 0.9              322.        17.4  340.    3.25
## 10 1                325.        18.8  365.   19.5
```

```
cor.test(summary.Observed$Predicted, summary.Observed$Found)
```

```
##
##  Pearson's product-moment correlation
##
## data:  summary.Observed$Predicted and summary.Observed$Found
## t = 5.7946, df = 8, p-value = 0.0004077
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.6196320 0.9760291
## sample estimates:
##       cor
## 0.8986587
```

```
m1 <- lm(summary.Observed$Predicted ~ -1 + summary.Observed$Found)
summary(m1)
```

```
##
## Call:
## lm(formula = summary.Observed$Predicted ~ -1 + summary.Observed$Found)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -40.560  -9.325   5.771  15.032  31.310
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## summary.Observed$Found   1.0026     0.0211   47.52 4.06e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 21.21 on 9 degrees of freedom
## Multiple R-squared:  0.996,Adjusted R-squared:  0.9956
## F-statistic:  2258 on 1 and 9 DF,  p-value: 4.058e-12
```

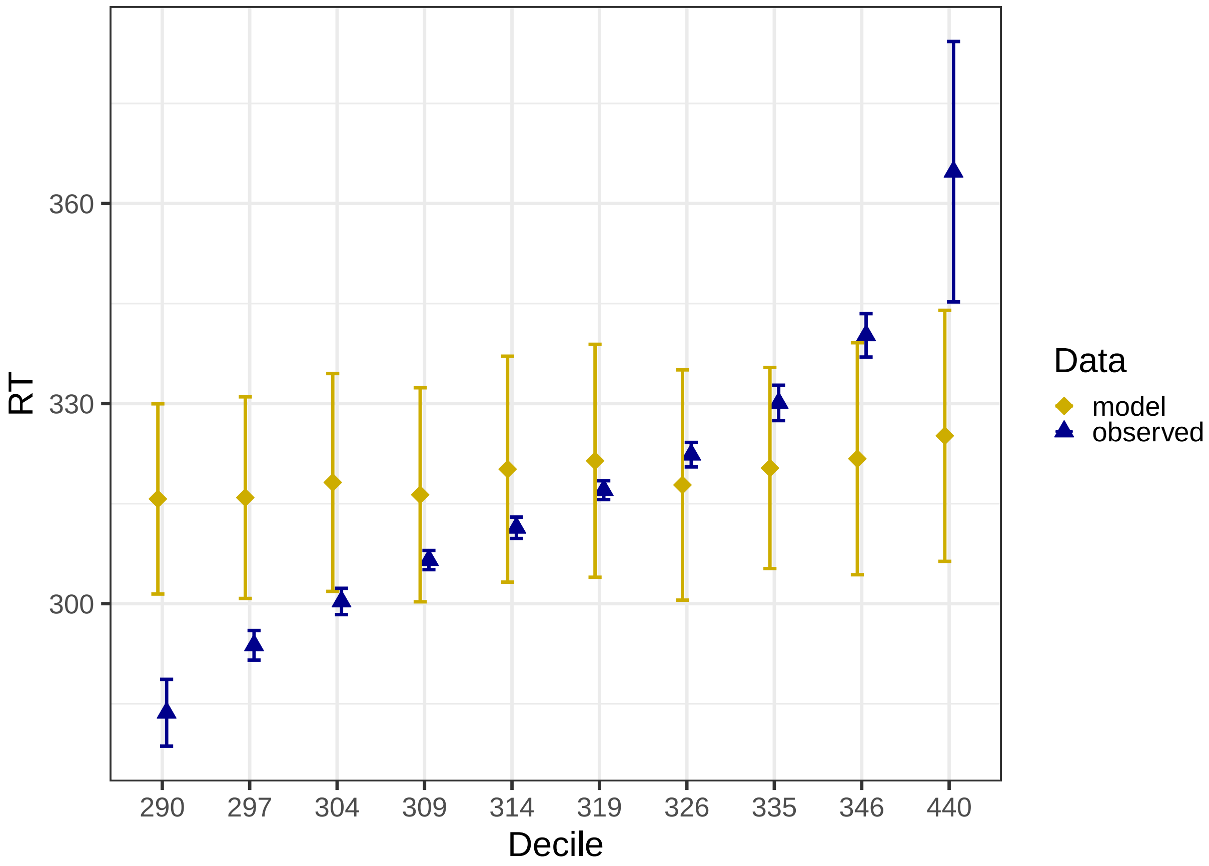
```
summary.Observed$Observedcat <- as.character(summary.Observed$Observedcat)

summary.Observed$Observedcat <- round(cutoff[2:11])

summary.Observed$Observedcat <- as.factor(summary.Observed$Observedcat)


data.to.plot <- data.frame(Decile = rep(summary.Observed$Observedcat, 2), RT = c(summary.Observed$Predi
    summary.Observed$Found), std = c(summary.Observed$sdPredicted, summary.Observed$sdFound),
    Data = c(rep("model", 10), rep("observed", 10)))

data.to.plot
```

```
##    Decile       RT       std     Data
## 1     290 315.7072 14.259645    model
## 2     297 315.8985 15.111654    model
## 3     304 318.1744 16.327556    model
## 4     309 316.3260 16.045432    model
## 5     314 320.1699 16.935492    model
## 6     319 321.4270 17.458987    model
## 7     326 317.7947 17.258142    model
## 8     335 320.3360 15.076059    model
## 9     346 321.7311 17.391639    model
## 10    440 325.1657 18.816902    model
## 11    290 283.6501  5.007106 observed
## 12    297 293.7607  2.220551 observed
## 13    304 300.3326  1.976318 observed
## 14    309 306.5420  1.442146 observed
## 15    314 311.3826  1.603889 observed
## 16    319 317.0160  1.413500 observed
## 17    326 322.3407  1.837590 observed
## 18    335 330.1012  2.654728 observed
## 19    346 340.2313  3.251219 observed
## 20    440 364.7646 19.519875 observed
```

```
library(ggplot2)

library(dplyr)


g1 <- ggplot(data.to.plot, aes(Decile, RT, color = Data, fill = Data, pch = Data))
g1 <- g1 + geom_point(position = dodge, size = I(5)) + geom_line(method = "lm",
    formula = RT ~ Decile) + geom_errorbar(aes(ymin = RT - std, ymax = RT +
    std), position = dodge, width = 0.3, size = I(1.3)) + scale_shape_manual(values = 23:24) +
    scale_color_manual(values = c("gold3", "blue4")) + scale_fill_manual(values = c("gold3",
    "blue4")) + theme_bw(28)
```

```
## Warning: Ignoring unknown parameters: method, formula
```

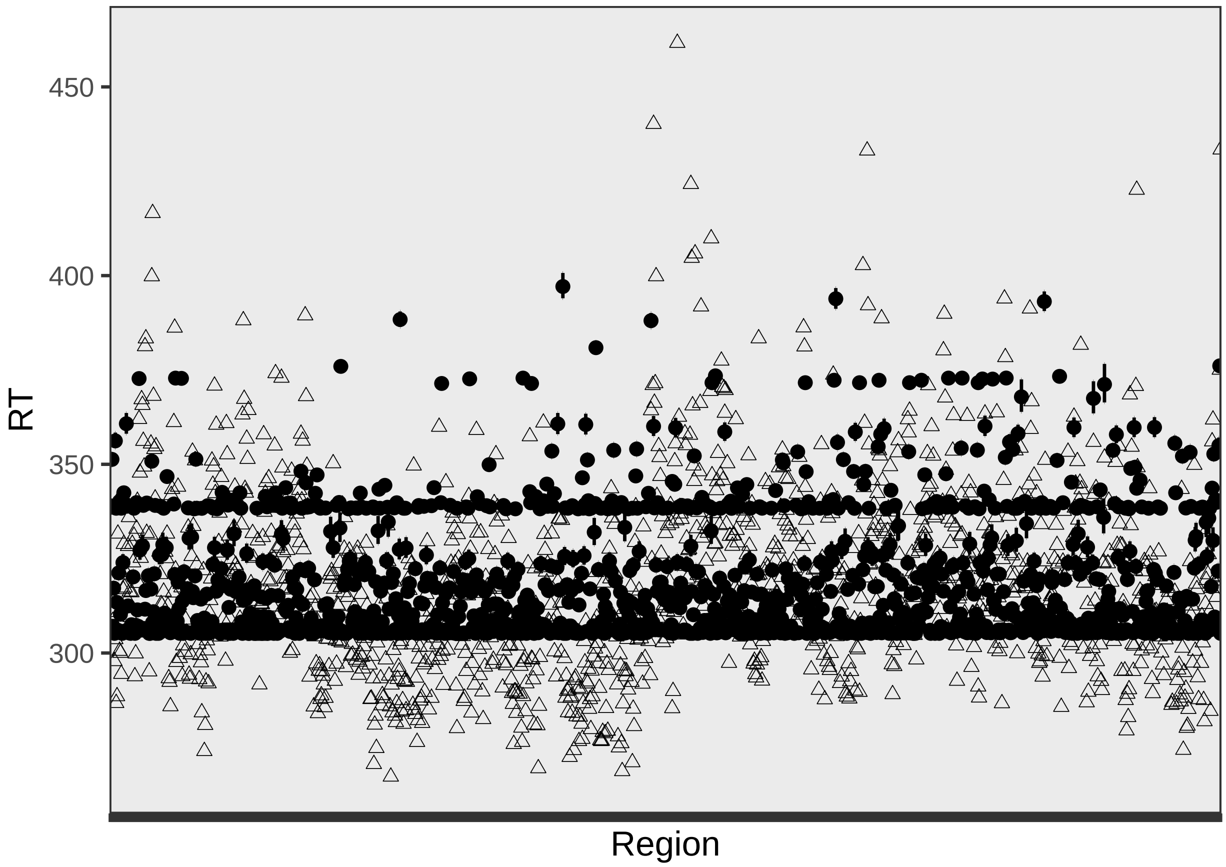
```
## geom_path: Each group consists of only one observation. Do you need to
## adjust the group aesthetic?
```



```
ggsave("direct.png", width = 19, height = 12)

## geom_path: Each group consists of only one observation. Do you need to
## adjust the group aesthetic?
```

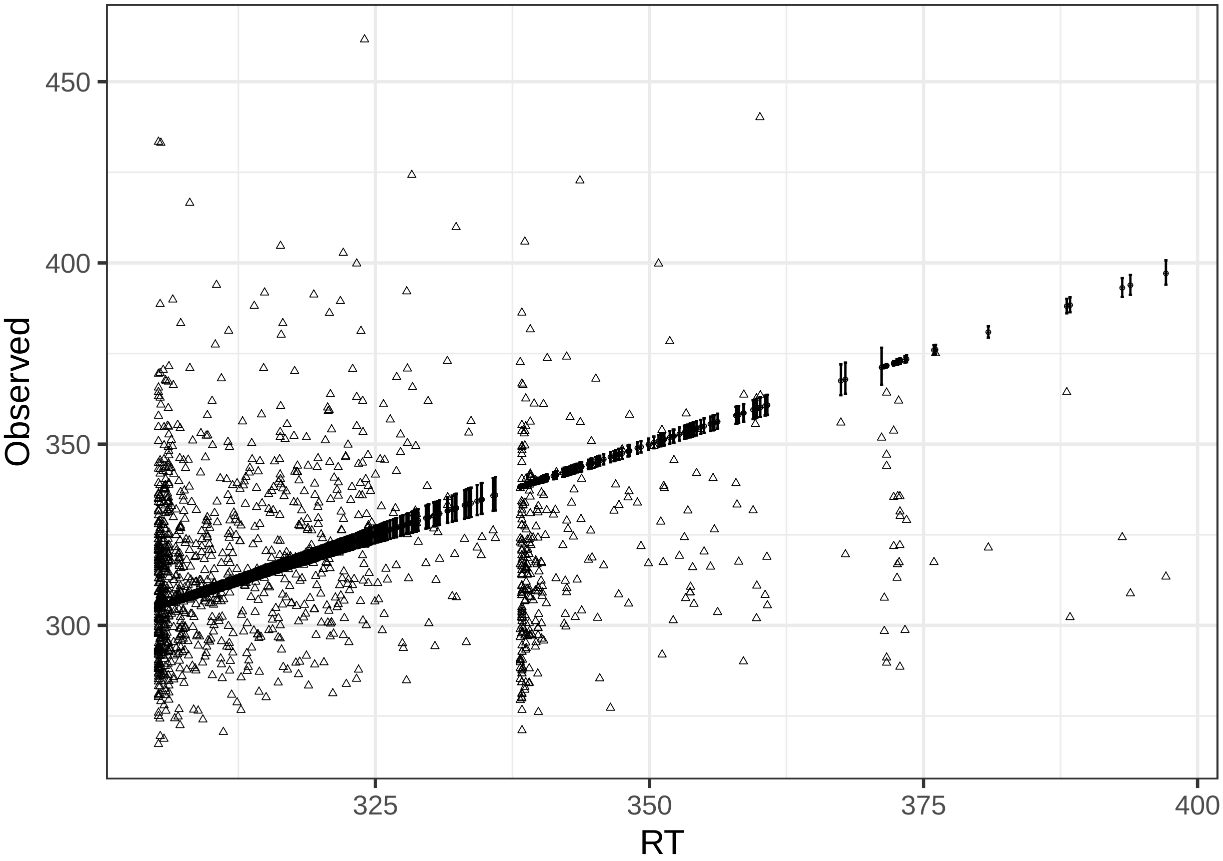
```
library(ggplot2)

library(dplyr)

dodge <- position_dodge(width = 0.2)

data.to.plot <- data.all %>% group_by(Region) %>% summarise(Region = first(Region),
    Word = first(Word), CF1 = quantile(RT, probs = c(0.05, 0.95))[1], CF2 = quantile(RT,
        probs = c(0.05, 0.95))[2], RT = mean(RT), Observed = first(Observed))

head(as.data.frame(data.to.plot), n = 30)

##     Region     Word     CF1   CF2       RT Observed
## 1  No_0001     said 306.100 307.5 306.7965 313.4706
## 2  No_0002     that 338.300 339.0 338.6296 306.6118
## 3  No_0003  whoever 349.600 353.0 351.3075 338.4706
## 4  No_0004    could 306.300 307.9 307.0910 308.4535
## 5  No_0005     kill 315.665 318.8 317.1842 310.8372
## 6  No_0006      the 305.100 305.4 305.2129 297.8235
## 7  No_0007     boar 354.300 358.4 356.2165 303.6471
## 8  No_0008      and 338.200 338.6 338.3613 286.7294
## 9  No_0009    bring 312.000 314.8 313.3989 288.5294
## 10 No_0010       as 305.600 306.6 306.0363 331.6118
## 11 No_0011    proof 319.400 323.2 321.2384 340.7294
## 12 No_0012      its 339.400 341.0 340.1558 300.5529
## 13 No_0013     head 309.000 311.5 310.2748 300.0235
## 14 No_0014       to 338.200 338.7 338.3726 294.4471
## 15 No_0015      the 305.100 305.4 305.2122 320.7647
## 16 No_0016    manor 321.800 326.2 323.9535 316.9059
## 17 No_0017    house 341.300 343.6 342.4565 328.8810
## 18 No_0018    would 339.000 340.3 339.6278 317.3333
## 19 No_0019       be 305.500 306.4 305.8833 321.4286
## 20 No_0020 rewarded 358.100 363.6 360.7593 305.4941
## 21 No_0021     with 338.500 339.4 338.9029 314.0941
## 22 No_0022     land 311.100 313.8 312.4871 328.3214
## 23 No_0023      and 305.200 305.6 305.3602 335.9762
## 24 No_0024      was 305.400 306.1 305.7151 316.2706
## 25 No_0025      the 305.100 305.4 305.2122 309.5301
## 26 No_0026   people 306.700 308.4 307.5020 316.0723
## 27 No_0027       of 305.200 305.6 305.3409 328.9036
## 28 No_0028 bradford 318.400 322.0 320.1783 324.0000
## 29 No_0029      and 338.200 338.6 338.3613 331.0353
## 30 No_0030      the 305.100 305.4 305.2122 293.8214
```

```
g1 <- ggplot(data.to.plot, aes(Region, RT))
g1 <- g1 + geom_point(position = dodge, size = I(5)) + geom_errorbar(aes(ymin = CF1,
    ymax = CF2), position = dodge, width = 0.3, size = I(1.3)) + scale_shape_manual(values = 21:24) +
    scale_color_manual(values = c("gold3", "blue4")) + scale_fill_manual(values = c("gold3",
    "blue4")) + theme_bw(28) + theme(axis.text.x = element_blank())
g1 <- g1 + geom_point(aes(x = Region, y = Observed), pch = 24, position = dodge,
    size = 4)
```



```
g1 <- ggplot(data.to.plot, aes(RT, Observed))
g1 <- g1 + geom_point(size = I(2), pch = 24) + geom_errorbar(aes(ymin = CF1,
    ymax = CF2), position = dodge, width = 0.3, size = I(0.9)) + scale_shape_manual(values = 21:24) +
    scale_color_manual(values = c("gold3", "blue4")) + scale_fill_manual(values = c("gold3",
    "blue4")) + theme_bw(28)
g1 <- g1 + geom_point(aes(x = RT, y = RT), pch = 10)
```

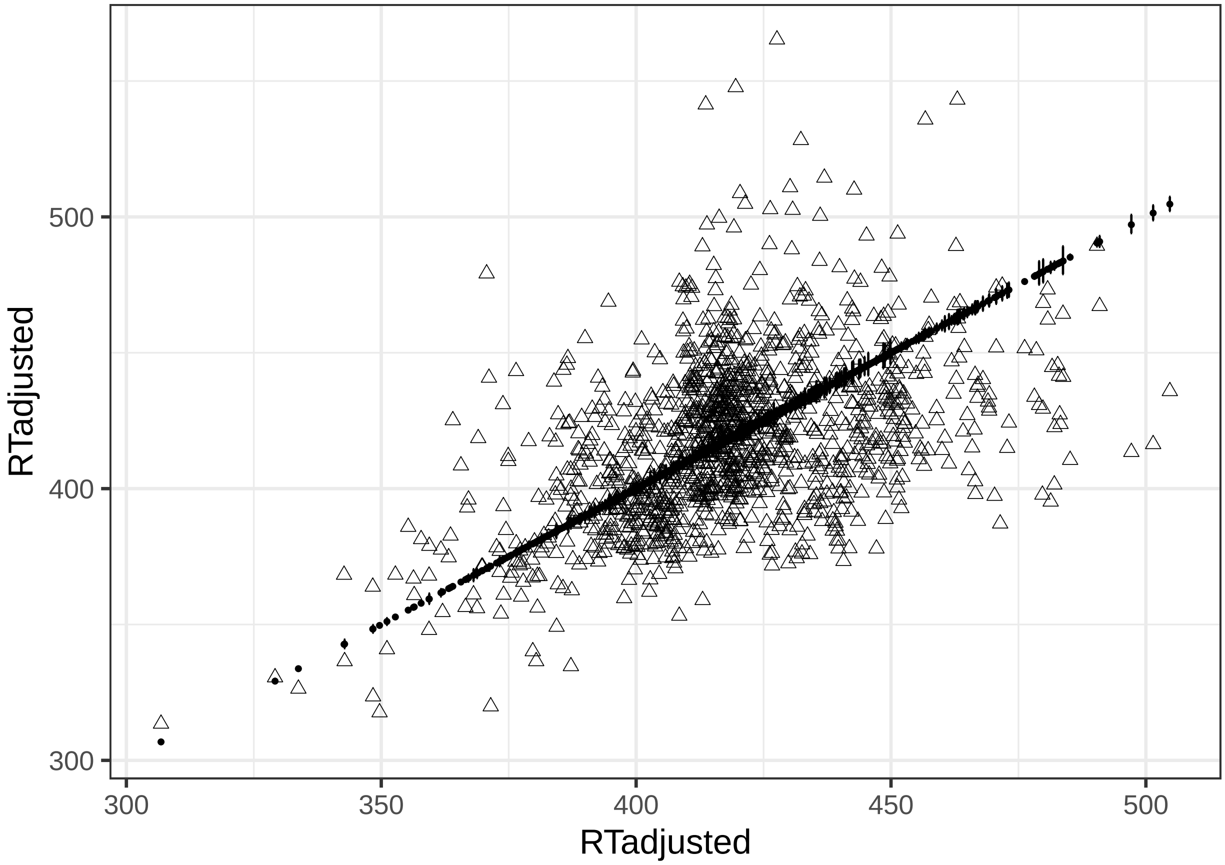
```
## Warning:  position_dodge requires non-overlapping x intervals
```



```
ggsave("predictions-observed.png")

## Saving 7 x 7 in image
## Warning: position_dodge requires non-overlapping x intervals
```

```
data.to.plot$RTadjusted <- data.to.plot$RT + m2$coefficients[3] * log(as.numeric(data.to.plot$Region))
data.to.plot$Observedadjusted <- data.to.plot$Observed + m2$coefficients[3] *
    log(as.numeric(data.to.plot$Region))
data.to.plot$CF1adjusted <- data.to.plot$CF1 + m2$coefficients[3] * log(as.numeric(data.to.plot$Region)
data.to.plot$CF2adjusted <- data.to.plot$CF2 + m2$coefficients[3] * log(as.numeric(data.to.plot$Region)

data.to.plot

## # A tibble: 1,311 x 10
##    Region Word    CF1   CF2    RT Observed RTadjusted Observedadjusted
##    <fct>  <fct> <dbl> <dbl> <dbl>    <dbl>      <dbl>            <dbl>
##  1 No_00~ said   306.  308.  307.     313.       307.             313.
##  2 No_00~ that   338.  339.  339.     307.       350.             318.
##  3 No_00~ whoe~  350.  353   351.     338.       369.             356.
##  4 No_00~ could  306.  308.  307.     308.       329.             331.
##  5 No_00~ kill   316.  319.  317.     311.       343.             336.
##  6 No_00~ the    305.  305.  305.     298.       334.             326.
##  7 No_00~ boar   354.  358.  356.     304.       387.             335.
##  8 No_00~ and    338.  339.  338.     287.       371.             320.
##  9 No_00~ bring  312.  315.  313.     289.       348.              324.
## 10 No_00~ as     306.  307.  306.     332.       343.              368.
## # ... with 1,301 more rows, and 2 more variables: CF1adjusted <dbl>,
## #   CF2adjusted <dbl>
```

```
g1 <- ggplot(data.to.plot, aes(RTadjusted, RTadjusted))
g1 <- g1 + geom_point(size = I(2)) + geom_errorbar(aes(ymin = CF1adjusted,
    ymax = CF2adjusted), width = 0.3, size = I(0.9)) + scale_shape_manual(values = 21:24) +
    scale_color_manual(values = c("gold3", "blue4")) + scale_fill_manual(values = c("gold2",
    "blue4")) + theme_bw(28)
g1 <- g1 + geom_point(aes(x = RTadjusted, y = Observedadjusted), pch = 24,
    size = 4)
```



```
ggsave("ns1.png")

## Saving 7 x 7 in image
```

4 Parameters

This last part shows the values of parameters and Rhat values.

4.1 LF

```
############# PARAMS###########
draws <- createdraws("lf")

str(draws)

##  num [1:807, 1:2] 0.0126 0.0126 0.0126 0.016 0.016 ...

Rhat(draws)

## [1] 1.036216
```

Mean etc.

```
tail(draws)

##              [,1]       [,2]
## [802,] 0.01420765 0.01337264
## [803,] 0.01420765 0.01337264
## [804,] 0.01420765 0.01337264
## [805,] 0.01420765 0.01337264
## [806,] 0.01420765 0.01337264
## [807,] 0.01420765 0.01337264

mean(c(draws[, 1:2]))

## [1] 0.01390178

median(c(draws[, 1:2]))

## [1] 0.01394016

sd(c(draws[, 1:2]))

## [1] 0.001022104
```

4.2 LE

```
############# PARAMS###########
draws <- createdraws("le")

str(draws)

##  num [1:807, 1:2] 0.653 0.653 0.647 0.647 0.647 ...

Rhat(draws)

## [1] 1.027879
```

Mean etc.

```
tail(draws)

##             [,1]      [,2]
## [802,] 0.6308769 0.6710766
## [803,] 0.6308769 0.6710766
## [804,] 0.6308769 0.6710766
## [805,] 0.6308769 0.6710766
## [806,] 0.6308769 0.6710766
## [807,] 0.6308769 0.6710766

mean(c(draws[, 1:2]))

## [1] 0.6611395

median(c(draws[, 1:2]))

## [1] 0.654711

sd(c(draws[, 1:2]))

## [1] 0.0681144
```