# Experiment 3 (self-paced reading)

R code to reproduce the analysis of Experiment 3 reported in the manuscript *"Does case marking affect agreement attraction in comprehension?"*.

## Participants

***Participant exclusion.*** In total 120 participants were recruited, but three participants were excluded because their primary language was Russian. As a result, data from 117 were included in the analysis.

Table 1: Summary of participants' demographic characteristics after participant exclusion was performed.

| age | gender | handedness | education | impairment | vision |
|---|---|---|---|---|---|
| Min. :18.00 | female:84 | left : 7 | higher :112 | head injury (hematoma): 1 | corrected :24 |
| 1st Qu.:18.00 | male :33 | right:110 | secondary : 4 | neurosis (no pills) : 1 | good :82 |
| Median :20.00 | | | vocational: 1 | none :115 | uncorrected near-sightedness:11 |
| Mean :21.85 | | | | | |
| 3rd Qu.:23.00 | | | | | |
| Max. :39.00 | | | | | |

## Contrast coding

Note that the term "interference" applies to sentences with singular attractors in grammatical sentences (i.e., "a" and "e") but plural attractors in ungrammatical sentences (i.e., "d" and "h").

### *Main effects and interactions*

```
# Contrasts to evaluate the main effects of case, number interference ('int'),
# sentence grammaticality ('gram'), and their interactions
##       a   b   c   d   e   f   g   h
#case  -1  -1  -1  -1   1   1   1   1 case match is -1, case mismatch is 1
#int    1  -1  -1   1   1  -1  -1   1 no-interference is -1, interference is 1
#gram   1   1  -1  -1   1   1  -1  -1 ungrammatical is -1, grammatical is 1

target$case<-ifelse(target$cond%in%c("a","b","c","d"),-1,1)
target$int<-ifelse(target$cond%in%c("b","c","f","g"),-1,1)
target$gram<-ifelse(target$cond%in%c("c","d","g","h"),-1,1)
target$casexint<-target$case*target$int
target$casexgram<-target$case*target$gram
target$intxgram<-target$int*target$gram
target$casexintxgram<-target$case*target$int*target$gram
```

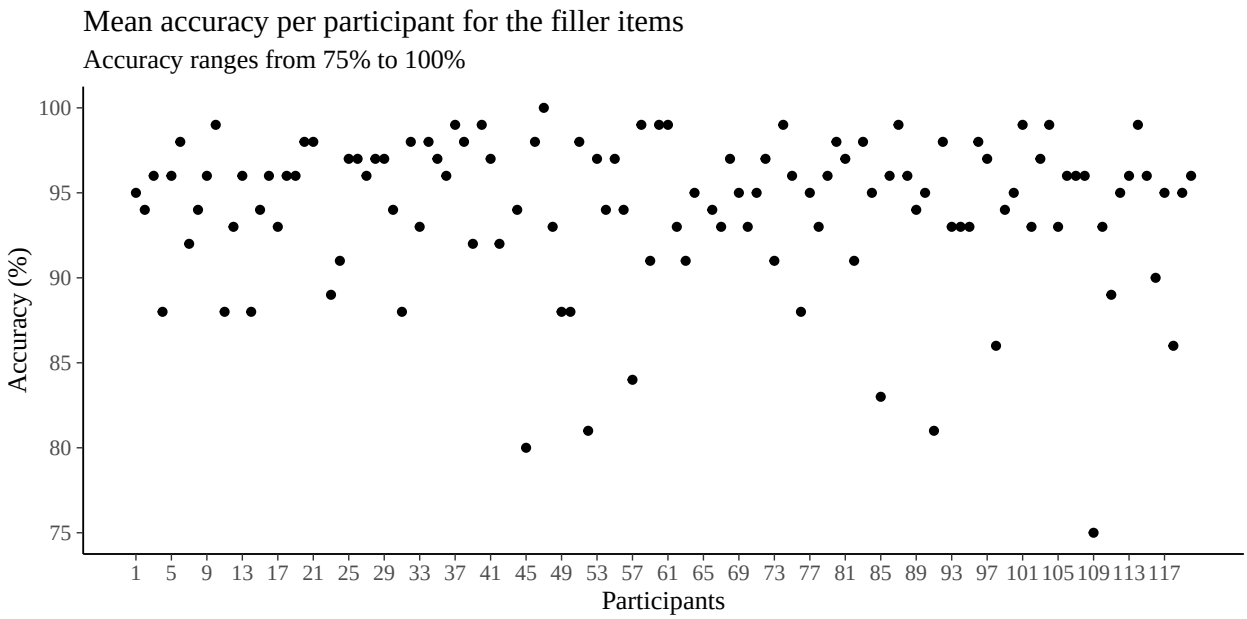
***Nested comparisons***

```
# Contrasts to evaluate the main effects of case, number interference ('int'),
# and their interaction for the grammatical (x_g) and ungrammatical (x_u)
# sentences separately.
##            a   b   c   d   e   f   g   h
# gram        1   1  -1  -1   1   1  -1  -1 ungrammatical is -1, grammatical is 1
# case_g     -1  -1   0   0   1   1   0   0 case match is -1, case mismatch is 1
# int_g       1  -1   0   0   1  -1   0   0 no-interference is -1, interference is 1
# casexint_g -1   1   0   0   1  -1   0   0

# case_u      0   0  -1  -1   0   0   1   1
# int_u       0   0  -1   1   0   0  -1   1
# casexint_u  0   0   1  -1   0   0  -1   1

target$case_g <- ifelse(target$cond%in%c("a","b"),-1,
                        ifelse(target$cond%in%c("e","f"),1,0))
target$int_g <- ifelse(target$cond%in%c("b","f"),-1,
                       ifelse(target$cond%in%c("a","e"),1,0))
target$casexint_g <- target$case_g*target$int_g
target$case_u <- ifelse(target$cond%in%c("c","d"),-1,
                        ifelse(target$cond%in%c("g","h"),1,0))
target$int_u <- ifelse(target$cond%in%c("c","g"),-1,
                       ifelse(target$cond%in%c("d","h"),1,0))
target$casexint_u <- target$case_u*target$int_u

# Contrasts to evaluate the number interference effect for the grammatical
# sentences but in case match (nominative attractor; attr_nom_g) and
# case mismatch (accusative attractor; attr_acc_g) conditions separately
##           a   b    e   f
#case-g     -1  -1   1   1 case match is -1, mismatch is 1
#attr_nom_g  1  -1   0   0 no-interference is -1, interference is 1
#attr_acc_g  0   0   1  -1
target$attr_nom_g<-ifelse(target$cond=="a",1,
                          ifelse(target$cond=="b",-1,0))
target$attr_acc_g<-ifelse(target$cond=="e",1,
                          ifelse(target$cond=="f",-1,0))
```

## Filler accuracy

- Overall accuracy (%) for the filler items

```
##   fillerAccuracy fillerSE
## 1           94.1      0.2
```



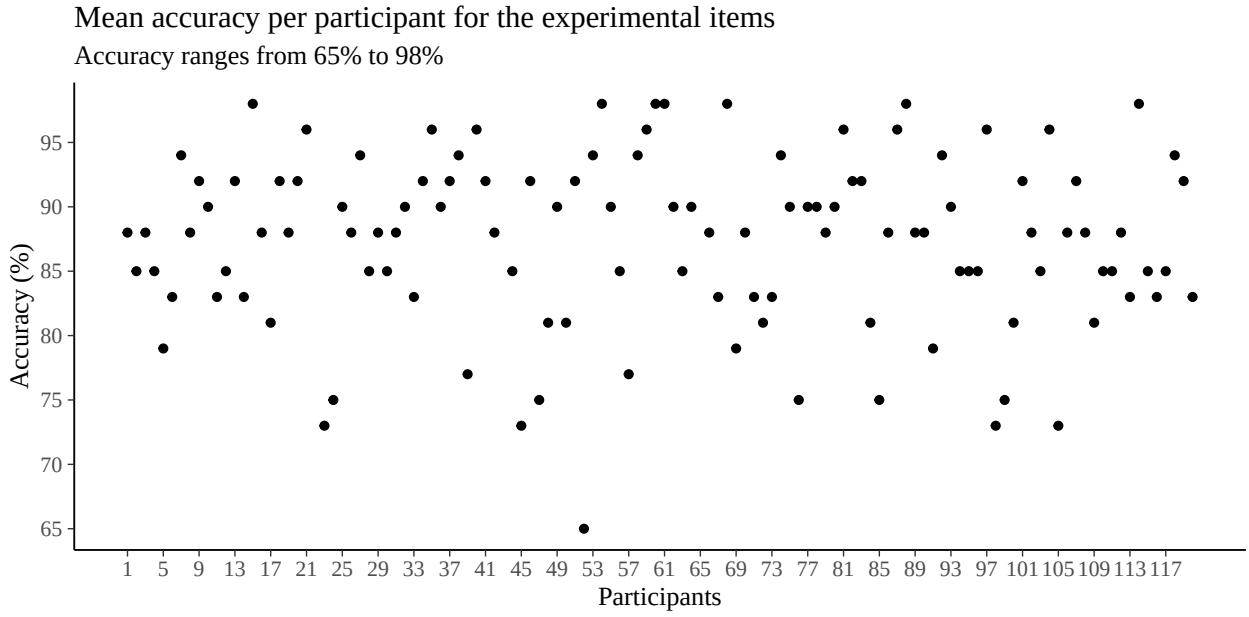
## Target accuracy

- Overall accuracy (%) for the experimental items

```
##   trgAccuracy trgSE
## 1        87.2   0.4
```

Table 2: Mean accuracy per condition for the experimental items. The term "interference" applies to sentences with singular attractors in grammatical sentences but plural attractors in ungrammatical sentences.

| | **Condition** | **Accuracy [%]** | **SE** |
|---|---|---|---|
| case match, grammatical, interference | a | 88.6 | 1.2 |
| case match, grammatical, no-interference | b | 88.0 | 1.2 |
| case match, ungrammatical, no-interference | c | 87.2 | 1.3 |
| case match, ungrammatical, interference | d | 87.3 | 1.3 |
| case mismatch, grammatical, interference | e | 87.2 | 1.3 |
| case mismatch, grammatical, no-interference | f | 86.5 | 1.3 |
| case mismatch, ungrammatical, no-interference | g | 87.2 | 1.3 |
| case mismatch, ungrammatical, interference | h | 85.8 | 1.3 |



## Reading time data

***RT trimming.*** RTs below 200ms and above 8000ms are excluded.

```
## percent of data points trimmed across all regions
targetTrimmed<-subset(targetRT, rt>200 & rt<8000)
round(100*((dim(targetRT)[1]-dim(targetTrimmed)[1])/dim(targetRT)[1]), digits=1)
```

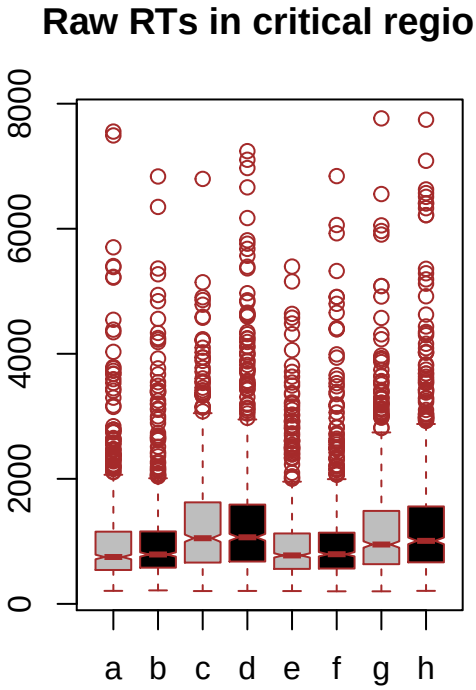
```
## [1] 0.5
```

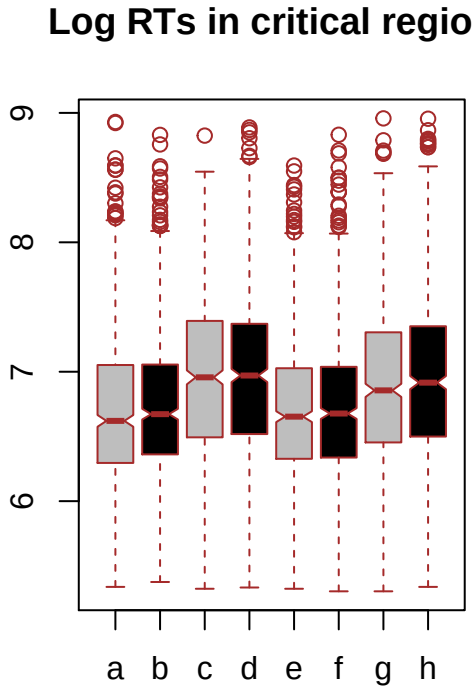
```
## percent of data points trimmed in the critical region
rcverb_trimmed<-subset(rcverb, rt>200 & rt<8000)
round(100*((dim(rcverb)[1]-dim(rcverb_trimmed)[1])/dim(rcverb)[1]),digits=2)
```

```
## [1] 0.71
```

```
## percent of data points trimmed in the post-critical region
rcadv1_trimmed<-subset(rcadv1, rt>200 & rt<8000)
round(100*((dim(rcadv1)[1]-dim(rcadv1_trimmed)[1])/dim(rcadv1)[1]),digits=2)
```

```
## [1] 0.28
```



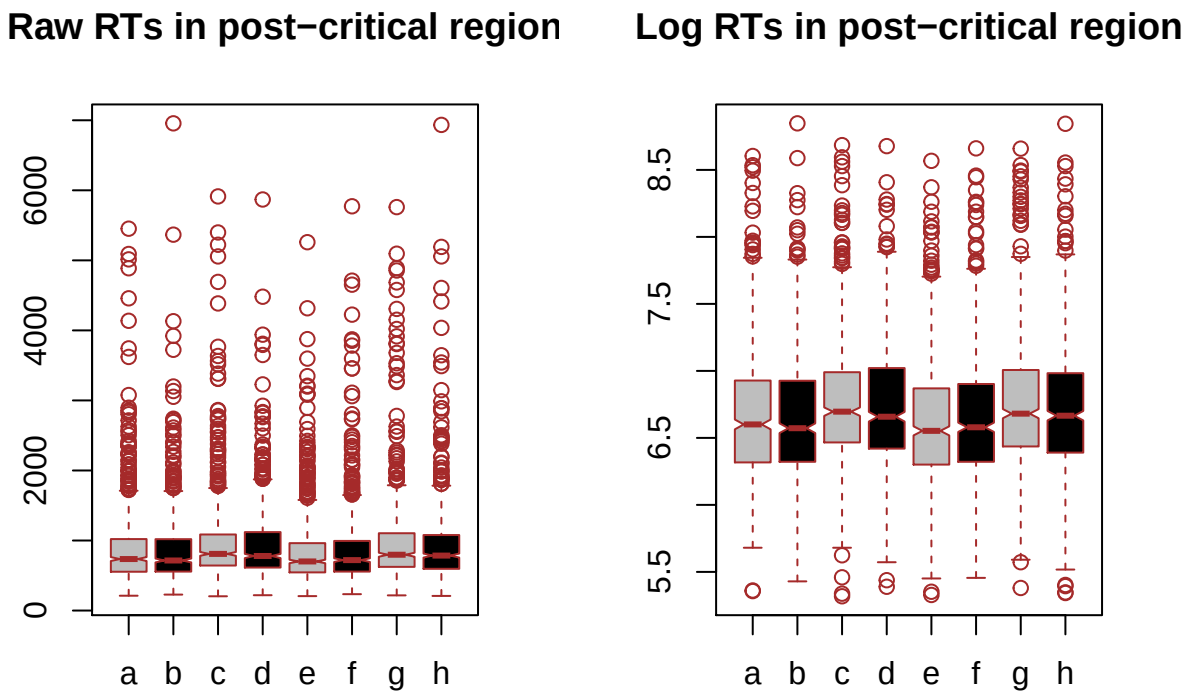



Table 3: Mean reading times in the critical region for the four conditions. The term "interference" applies to sentences with singular attractors in grammatical sentences but plural attractors in ungrammatical sentences.

| | **Condition** | **Mean RT [ms]** | **SE** |
|---|---|---|---|
| case match, grammatical, interference | a | 1021 | 32 |
| case match, grammatical, no-interference | b | 1016 | 30 |
| case match, ungrammatical, no-interference | c | 1279 | 33 |
| case match, ungrammatical, interference | d | 1344 | 40 |
| case mismatch, grammatical, interference | e | 978 | 27 |
| case mismatch, grammatical, no-interference | f | 1015 | 30 |
| case mismatch, ungrammatical, no-interference | g | 1229 | 35 |
| case mismatch, ungrammatical, interference | h | 1330 | 41 |

Table 4: Mean reading times in the post-critical region for the four conditions. The term "interference" applies to sentences with singular attractors in grammatical sentences but plural attractors in ungrammatical sentences.

| | **Condition** | **Mean RT [ms]** | **SE** |
|---|---|---|---|
| case match, grammatical, interference | a | 916 | 24 |
| case match, grammatical, no-interference | b | 880 | 22 |
| case match, ungrammatical, no-interference | c | 977 | 24 |
| case match, ungrammatical, interference | d | 947 | 21 |
| case mismatch, grammatical, interference | e | 865 | 21 |
| case mismatch, grammatical, no-interference | f | 883 | 22 |
| case mismatch, ungrammatical, no-interference | g | 972 | 25 |
| case mismatch, ungrammatical, interference | h | 944 | 23 |

## Priors

```
# Priors for reading time analysis involving main effects and interactions
priors_three_way <- c(set_prior("normal(0,10)", class="Intercept"),
                      set_prior("normal(0,1)", class="b", coef="case"),
                      set_prior("normal(0,1)", class="b", coef="int"),
                      set_prior("normal(0,1)", class="b", coef="gram"),
                      set_prior("normal(0,1)", class="b", coef="casexint"),
                      set_prior("normal(0,1)", class="b", coef="casexgram"),
                      set_prior("normal(0,1)", class="b", coef="intxgram"),
                      set_prior("normal(0,1)", class="b", coef="casexintxgram"),
                      set_prior("normal(0,1)", class="sd"),
                      set_prior("normal(0,1)", class="sigma"),
                      set_prior("lkj(2)", class="cor"))
```

```
# Priors for reading time analysis involving nested comparisons to evaluate
#  the effects of case, number interference, and their interaction within
# grammatical and ungrammatical sentences separately.
priors_nested<- c(set_prior("normal(0,10)", class="Intercept"),
                  set_prior("normal(0,1)", class="b", coef="gram"),
                  set_prior("normal(0,1)", class="b", coef="case_g"),
                  set_prior("normal(0,1)", class="b", coef="int_g"),
                  set_prior("normal(0,1)", class="b", coef="casexint_g"),
                  set_prior("normal(0,1)", class="b", coef="case_u"),
                  set_prior("normal(0,1)", class="b", coef="int_u"),
                  set_prior("normal(0,1)", class="b", coef="casexint_u"),
                  set_prior("normal(0,1)", class="sd"),
                  set_prior("normal(0,1)", class="sigma"),
                  set_prior("lkj(2)", class="cor"))

# Priors for reading time analysis involving nested comparisons to evaluate
# the effect of number interference for the grammatical sentences but in
# case match and case mismatch conditions separately.
priors_nested_g<- c(set_prior("normal(0,10)", class="Intercept"),
                  set_prior("normal(0,1)", class="b", coef="case_g"),
                  set_prior("normal(0,1)", class="b", coef="attr_nom_g"),
                  set_prior("normal(0,1)", class="b", coef="attr_acc_g"),
                  set_prior("normal(0,1)", class="sd"),
                  set_prior("normal(0,1)", class="sigma"),
                  set_prior("lkj(2)", class="cor"))
```

## Reading time analysis results

In the tables below, each effect is described in terms of its posterior mean on log scale and the lower and upper bound of 95% credible interval.

### Critical region

Table 5: Analysis results for the reading times in the critical region showing estimates for the main effects case, number interference ('int'), grammaticality ('gram'), and their interactions.

| | Estimate | Est.Error | Q2.5 | Q97.5 |
|---|---|---|---|---|
| Intercept | 6.8362405 | 0.0449599 | 6.7449103 | 6.9234364 |
| case | -0.0103139 | 0.0069947 | -0.0236612 | 0.0033288 |
| int | 0.0038330 | 0.0068358 | -0.0097017 | 0.0170678 |
| gram | -0.1119016 | 0.0095451 | -0.1309884 | -0.0935470 |
| casexint | 0.0031893 | 0.0066990 | -0.0101052 | 0.0158440 |
| casexgram | 0.0080773 | 0.0065578 | -0.0046078 | 0.0207677 |
| intxgram | -0.0158087 | 0.0067360 | -0.0289134 | -0.0026113 |
| casexintxgram | -0.0047846 | 0.0064897 | -0.0173187 | 0.0078862 |

#### *Model estimates back-transformed to milliseconds*

```
##   Estimate_case  95% CrI
## 1        -19 ms [-45, 6]
```

```
##   Estimate_int   95% CrI
## 1         7 ms [-18, 32]
```

```
##   Estimate_gram      95% CrI
## 1       -209 ms [-251, -169]
```

```
##   Estimate_casexint   95% CrI
## 1              6 ms [-19, 29]
```

```
##   Estimate_casexgram  95% CrI
## 1              15 ms [-9, 39]
```

```
##   Estimate_intxgram   95% CrI
## 1            -30 ms [-54, -5]
```

```
##   Estimate_casexintxgram   95% CrI
## 1                  -9 ms [-32, 15]
```

Table 6: Analysis results for the reading times in the critical region showing estimates for the main effects of case, number interference ('int'), and their interaction within grammatical (x_g) and ungrammatical (x_u) sentences separately. Gram = grammaticality.

| | Estimate | Est.Error | Q2.5 | Q97.5 |
|---|---|---|---|---|
| Intercept | 6.8342941 | 0.0415421 | 6.7479369 | 6.9125015 |
| gram | -0.1121185 | 0.0093640 | -0.1300529 | -0.0936383 |
| case_g | -0.0020917 | 0.0088300 | -0.0195235 | 0.0152329 |
| int_g | -0.0119430 | 0.0090165 | -0.0296872 | 0.0056609 |
| casexint_g | -0.0016394 | 0.0090047 | -0.0189895 | 0.0164197 |
| case_u | -0.0184830 | 0.0105815 | -0.0394792 | 0.0022935 |
| int_u | 0.0193817 | 0.0103760 | -0.0009696 | 0.0404683 |
| casexint_u | 0.0079778 | 0.0090844 | -0.0099707 | 0.0256995 |

### *Model estimates back-transformed to milliseconds*

```
##   Estimate_case_grammatical   95% CrI
## 1                     -4 ms [-36, 28]
```

```
##   Estimate_int_grammatical   95% CrI
## 1                   -22 ms [-55, 11]
```

```
##   Estimate_casexint_grammatical   95% CrI
## 1                         -3 ms [-35, 31]
```

```
##   Estimate_case_ungrammatical  95% CrI
## 1                     -34 ms [-74, 4]
```

```
##   Estimate_int_ungrammatical  95% CrI
## 1                     36 ms [-2, 75]
```

```
##   Estimate_casexint_ungrammatical   95% CrI
## 1                           15 ms [-19, 48]
```

## Post-critical region

Table 7: Analysis results for the reading times in the post-critical region showing estimates for the main effects case, number interference ('int'), grammaticality ('gram'), and their interactions.

| | Estimate | Est.Error | Q2.5 | Q97.5 |
|---|---|---|---|---|
| Intercept | 6.6868825 | 0.0379655 | 6.6106700 | 6.7588180 |
| case | -0.0074984 | 0.0050470 | -0.0172750 | 0.0024824 |
| int | -0.0052851 | 0.0052198 | -0.0158416 | 0.0049096 |
| gram | -0.0440853 | 0.0077073 | -0.0591674 | -0.0291692 |
| casexint | -0.0064091 | 0.0050844 | -0.0164793 | 0.0036681 |
| casexgram | -0.0022857 | 0.0051733 | -0.0123366 | 0.0079000 |
| intxgram | 0.0075815 | 0.0051949 | -0.0026707 | 0.0176831 |
| casexintxgram | -0.0047555 | 0.0049427 | -0.0142718 | 0.0046798 |

### *Model estimates back-transformed to milliseconds*

```
##   Estimate_case  95% CrI
```

```
## 1        -12 ms [-28, 4]
```

```
##   Estimate_int  95% CrI
## 1        -8 ms [-25, 8]
```

```
##   Estimate_gram    95% CrI
## 1        -71 ms [-94, -47]
```

```
##   Estimate_casexint  95% CrI
## 1            -10 ms [-26, 6]
```

```
##   Estimate_casexgram   95% CrI
## 1              -4 ms [-20, 13]
```

```
##   Estimate_intxgram  95% CrI
## 1             12 ms [-4, 29]
```

```
##   Estimate_casexintxgram  95% CrI
## 1                  -8 ms [-23, 7]
```

Table 8: Analysis results for the reading times in the post-critical region showing estimates for the main effects of case, number interference ('int'), and their interaction within grammatical (x_g) and ungrammatical (x_u) sentences separately. Gram = grammaticality.

| | **Estimate** | **Est.Error** | **Q2.5** | **Q97.5** |
|---|---|---|---|---|
| Intercept | 6.6886713 | 0.0398284 | 6.6099133 | 6.7648259 |
| gram | -0.0440598 | 0.0080197 | -0.0591109 | -0.0279864 |
| case_g | -0.0097700 | 0.0073487 | -0.0243149 | 0.0050337 |
| int_g | 0.0024139 | 0.0072262 | -0.0117565 | 0.0165899 |
| casexint_g | -0.0110766 | 0.0076541 | -0.0258692 | 0.0040268 |
| case_u | -0.0053259 | 0.0070733 | -0.0193500 | 0.0088606 |
| int_u | -0.0131418 | 0.0078046 | -0.0283491 | 0.0021142 |
| casexint_u | -0.0014539 | 0.0068998 | -0.0146930 | 0.0124459 |

### *Model estimates back-transformed to milliseconds*

```
##   Estimate_case_grammatical  95% CrI
## 1                  -16 ms [-39, 8]
```

```
##   Estimate_int_grammatical   95% CrI
## 1                   4 ms [-19, 27]
```

```
##   Estimate_casexint_grammatical  95% CrI
## 1                       -18 ms [-42, 6]
```

```
##   Estimate_case_ungrammatical   95% CrI
## 1                      -9 ms [-31, 14]
```

```
##   Estimate_int_ungrammatical  95% CrI
## 1                    -21 ms [-46, 3]
```

```
##   Estimate_casexint_ungrammatical   95% CrI
## 1                          -2 ms [-24, 20]
```

Table 9: Analysis results showing estimates for the effect of number interference in the post-critical region for the grammatical sentences but in case match (nominative attractor; attr_nom_g) and case mismatch (accusative attractor; attr_acc_g) conditions separately.

| | **Estimate** | **Est.Error** | **Q2.5** | **Q97.5** |
|---|---|---|---|---|
| Intercept | 6.6918571 | 0.0386825 | 6.6192792 | 6.7718457 |
| case_g | -0.0098356 | 0.0073816 | -0.0243652 | 0.0046294 |
| attr_nom_g | 0.0134099 | 0.0109228 | -0.0081923 | 0.0349338 |
| attr_acc_g | -0.0091253 | 0.0102113 | -0.0291449 | 0.0106320 |

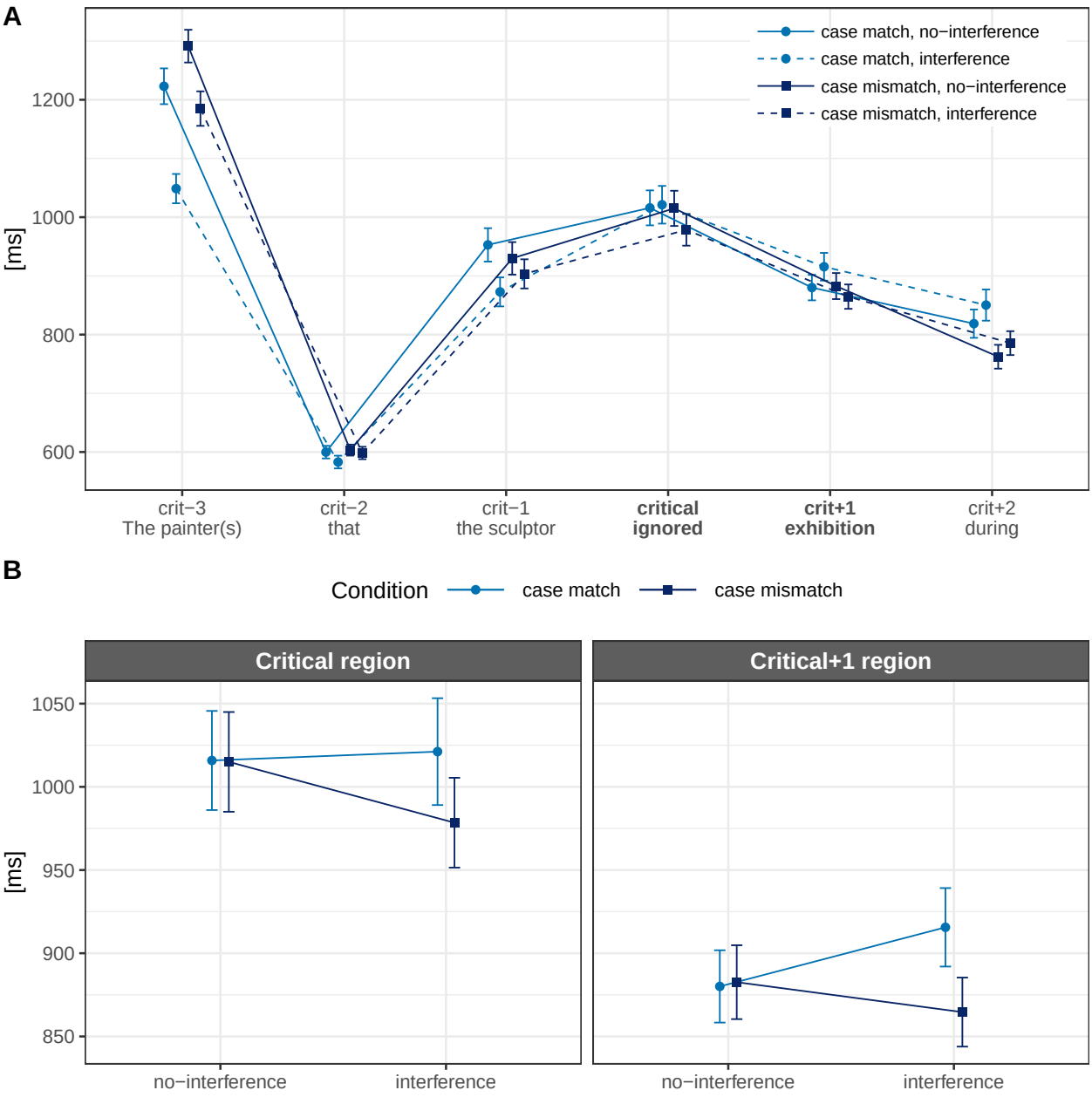
### *Model estimates back-transformed to milliseconds*

```
##   Estimate_interference_caseMatch   95% CrI
## 1                          22 ms [-14, 57]
```

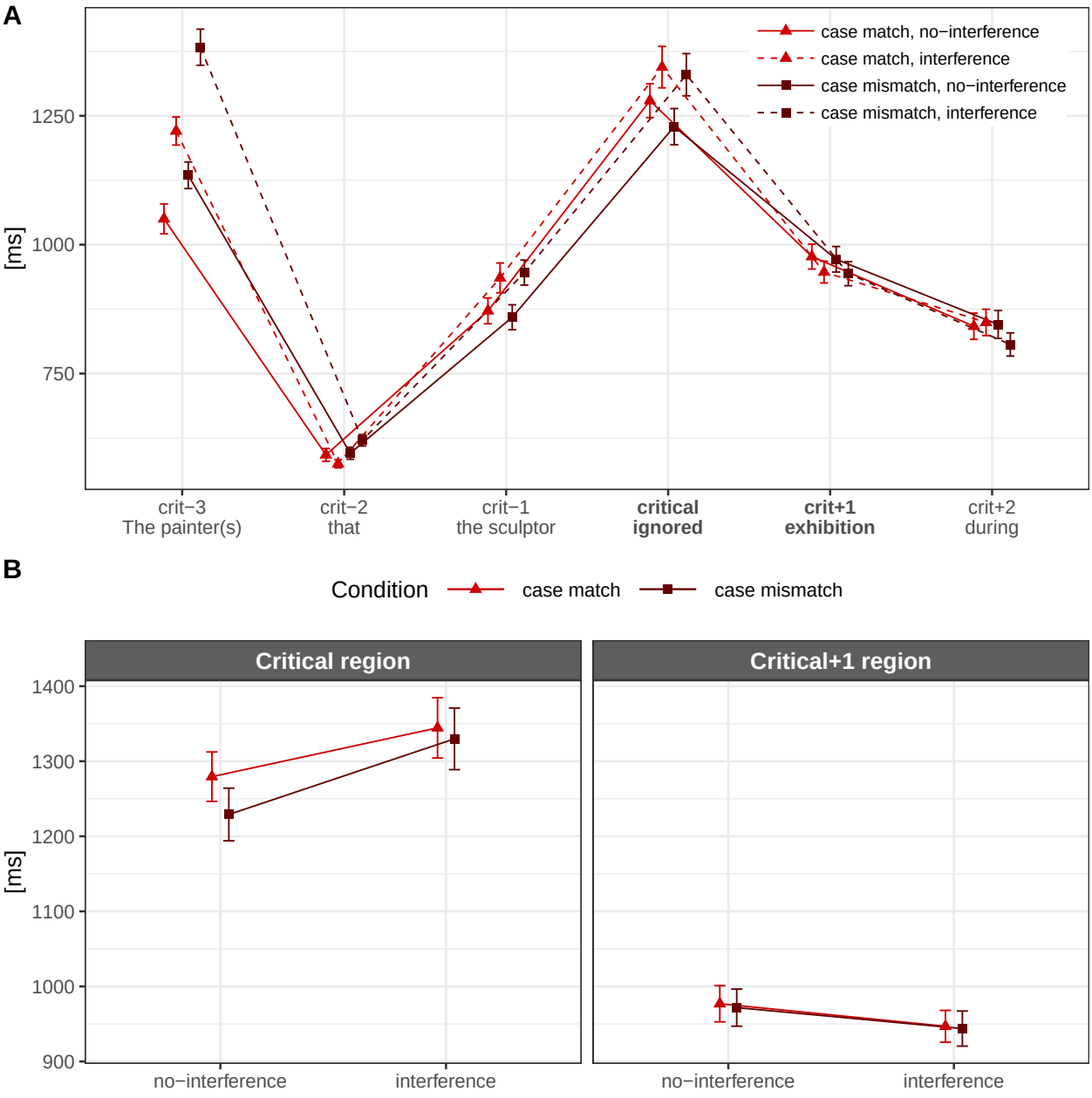
```
##   Estimate_interference_caseMismatch   95% CrI
## 1                           -15 ms [-47, 17]
```

# Plots

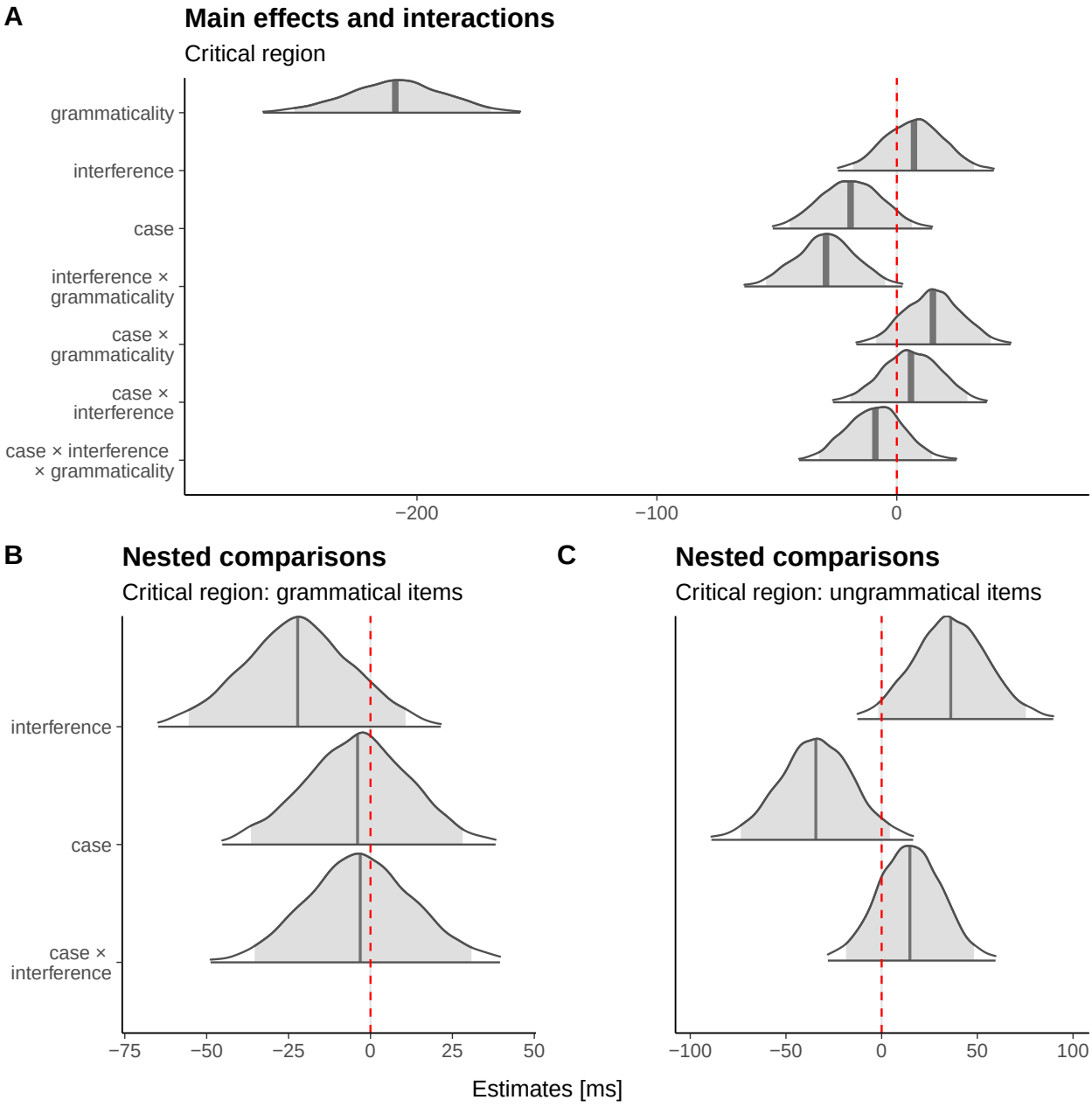
## By-region RTs for grammatical sentences

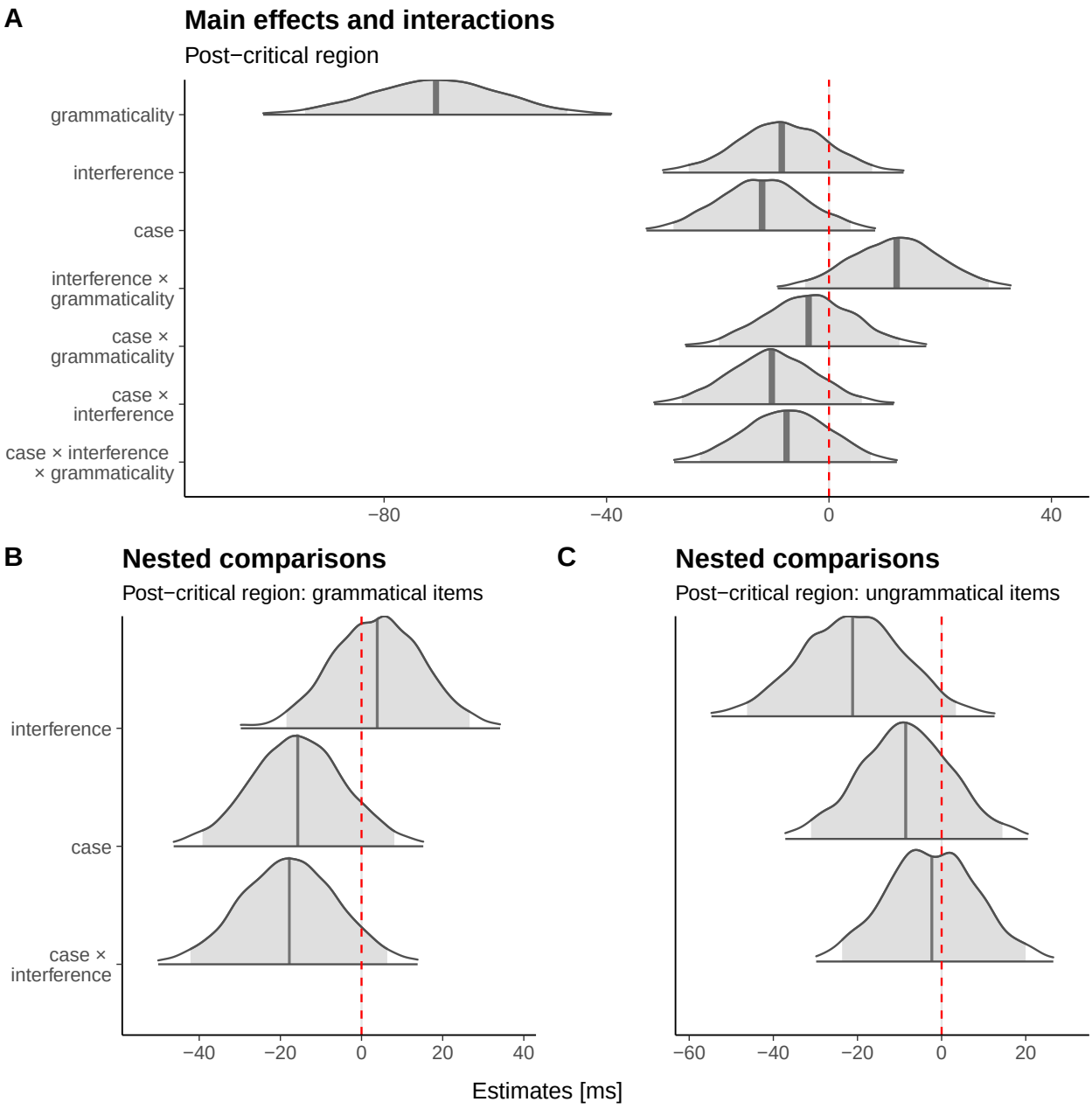


## By-region RTs for ungrammatical sentences



Density plots




A
Main effects and interactions
Post−critical region
grammaticality
interference
case
interference × grammaticality
case × grammaticality
case × interference
case × interference × grammaticality
−80
−40
0
40
B
Nested comparisons
Post−critical region: grammatical items
interference
case
case × interference
−40
−20
0
20
40
C
Nested comparisons
Post−critical region: ungrammatical items
−60
−40
−20
0
20
Estimates [ms]