

model2

Lab B Team 2

```
spa3<-read.csv('spa3.csv')

eng3<-read.csv('eng3.csv')

#logistic regression model for english data:
M1<-glm(accuracy~cognate, family=binomial(link="logit"),data=eng3)
summary(M1)

##
## Call:
## glm(formula = accuracy ~ cognate, family = binomial(link = "logit"),
##      data = eng3)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -1.0842  -1.0842  -0.9424   1.2735   1.4322
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -0.58151    0.08555  -6.797 1.07e-11 ***
## cognate      0.35836    0.11890   3.014 0.00258 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 1600.5  on 1187  degrees of freedom
## Residual deviance: 1591.4  on 1186  degrees of freedom
## AIC: 1595.4
##
## Number of Fisher Scoring iterations: 4

#Intercept and coefficient for cognate:
inv.logit(-0.58)

## [1] 0.3589326

inv.logit(-0.58+0.35)

## [1] 0.4427521

#logistic regression model for spanish data:
M2<-glm(accuracy~cognate, family=binomial(link="logit"),data=spa3)
summary(M2)

##
## Call:
```

```
## glm(formula = accuracy ~ cognate, family = binomial(link = "logit"),
##     data = spa3)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -0.9341  -0.9341  -0.7004   1.4421   1.7466
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept) -1.28007    0.09953 -12.861  < 2e-16 ***
## cognate      0.67654    0.13143   5.148 2.64e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##      Null deviance: 1420.0  on 1186  degrees of freedom
## Residual deviance: 1392.9  on 1185  degrees of freedom
## (1 observation deleted due to missingness)
## AIC: 1396.9
##
## Number of Fisher Scoring iterations: 4
```

```
inv.logit(-1.28)
```

```
## [1] 0.2175502
```

```
inv.logit(-1.28+0.67)
```

```
## [1] 0.3520592
```

Add random variable into logistic model

```
M3 <- glmer(accuracy~1+(1|cognate),data=eng3,family=binomial(link="logit"))
print(M3)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
## Approximation) [glmerMod]
## Family: binomial ( logit )
## Formula: accuracy ~ 1 + (1 | cognate)
## Data: eng3
##      AIC      BIC    logLik deviance df.resid
## 1600.4328 1610.5929 -798.2164 1596.4328     1186
## Random effects:
## Groups Name          Std.Dev.
## cognate (Intercept) 0.1585
## Number of obs: 1188, groups: cognate, 2
## Fixed Effects:
## (Intercept)
##      -0.4016
```

```
M4 <- glmer(accuracy~1+(1|cognate),data=spa3,family=binomial(link="logit"))
print(M4)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
## Approximation) [glmerMod]
```

```
## Family: binomial ( logit )
## Formula: accuracy ~ 1 + (1 | cognate)
## Data: spa3
##      AIC      BIC    logLik deviance df.resid
## 1404.1287 1414.2871 -700.0644 1400.1287    1185
## Random effects:
## Groups Name      Std.Dev.
## cognate (Intercept) 0.326
## Number of obs: 1187, groups: cognate, 2
## Fixed Effects:
## (Intercept)
##      -0.94
```

refit the model with subject levels

```
M5 <- glmer(accuracy~cognate+(1|subject)+diff,data=eng3,family=binomial(link="logit"))
print(summary(M5))
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
## Approximation) [glmerMod]
## Family: binomial ( logit )
## Formula: accuracy ~ cognate + (1 | subject) + diff
## Data: eng3
##
##      AIC      BIC    logLik deviance df.resid
##    947.9    968.2   -469.9    939.9    1184
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -4.9507 -0.3735 -0.0971  0.3559  5.2318
##
## Random effects:
## Groups Name      Variance Std.Dev.
## subject (Intercept) 6.617    2.572
## Number of obs: 1188, groups: subject, 27
##
## Fixed effects:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  2.08652    0.56691   3.681 0.000233 ***
## cognate      0.74409    0.17385   4.280 1.87e-05 ***
## diff        -0.88052    0.07006 -12.568 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##      (Intr) cognat
## cognate -0.096
## diff    -0.410 -0.153
```

```
inv.logit(2.08652)
```

```
## [1] 0.8895861
```

```
inv.logit(2.08652+0.74409)
```

```
## [1] 0.9443077
```

```
inv.logit(2.08652-0.8832)
```

```
## [1] 0.7691149
```

Interpret: Intercept: For non-cognate words with same difficulty level, the possibility of answer the words accurately is 88.96%. Cognate: Words with same difficulty level, cognate words tend to have 94.43% higher possibility to be correctly answered. diff: For non-Cognates word, it has 76.91% higher possibility to be correctly answered as the difficulty increasing.

```
M6 <- glmer(accuracy~cognate+(1|subject)+diff,data=spa3,family=binomial(link="logit"))
print(summary(M6))
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
## Approximation) [glmerMod]
## Family: binomial ( logit )
## Formula: accuracy ~ cognate + (1 | subject) + diff
## Data: spa3
##
##      AIC      BIC   logLik deviance df.resid
##    965.1    985.4   -478.5    957.1     1183
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -4.0504 -0.4155 -0.1654  0.3529  6.0991
##
## Random effects:
##  Groups Name      Variance Std.Dev.
## subject (Intercept) 4.1      2.025
## Number of obs: 1187, groups: subject, 27
##
## Fixed effects:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)  0.84823    0.46092   1.840  0.0657 .
## cognate      1.16385    0.17533   6.638 3.18e-11 ***
## diff        -0.83898    0.06712 -12.500 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##              (Intr) cognat
## cognate -0.112
## diff    -0.402 -0.256
```

Interpret: Intercept: For non-cognate words with same difficulty level, the possibility of answer the words accurately is 74.17%. Cognate: Words with same difficulty level, cognate words tend to have 76.195% higher possibility to be correctly answered. diff: For non-Cognates word, it has 30.2% higher possibility to be correctly answered as the difficulty increasing.

```
inv.logit(0.84823)
```

```
## [1] 0.7001957
```

```
inv.logit(0.84823+1.16385)
```

```
## [1] 0.8820596
```

```
inv.logit(0.84823-0.83898)
```

```
## [1] 0.5023125
```

Interpret: Intercept: For non-cognate words with same difficulty level, the possibility of answer the words accurately is 70.02%. Cognate: Words with same difficulty level, cognate words tend to have 88.20% higher possibility to be correctly answered. diff: For non-Cognates word, it has 50.23% higher possibility to be correctly answered as the difficulty increasing.

Mixed effect logistic regression

```
#comb <- read.csv("comb.csv",header=T)
#comb <- unite(comb,"accuracy",c("eng.acc","spa.acc"),sep="",remove = F)
#comb<- comb[-115,]
#comb$category <- rep(NA,1143)
#for (i in 1:1143){
  # if (comb$eng.acc[i] == 0 && comb$spa.acc[i] == 0) {
    # comb$category[i] <- 1
  #}
  #if (comb$eng.acc[i] == 0 && comb$spa.acc[i] == 1) {
    # comb$category[i] <- 2
  #}
  ## if (comb$eng.acc[i] == 1 && comb$spa.acc[i] == 0) {
    # comb$category[i] <- 3
  #}
  # if (comb$eng.acc[i] == 1 && comb$spa.acc[i] == 1) {
    # comb$category[i] <- 4
  # }
}

#multinomial model
#M7 <- polr(factor(category)~cognate+diff,data=comb)
#print(summary(M7))
```

Try Multinomial analysis with brms

Note: One NA in spa3: no accuracy for word “knocker” (ID: BUBA46).

```
M7 <- brm(accuracy~cognate+(1|subject)+diff,data=spa3,family=bernoulli,prior = c(set_prior("normal(0,8)

## Warning: Rows containing NAs were excluded from the model.

## Compiling Stan program...

## Trying to compile a simple C file

## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## clang -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.frame
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
## namespace Eigen {
## ^
```

```

##          ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc.
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: f
## #include <complex>
##          ~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1

## Start sampling

##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 0.000219 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 2.19 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 1: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 1: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 1: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 1: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 1: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 1: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 1: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 1: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 1: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 1: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 1: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 1:
## Chain 1: Elapsed Time: 1.78307 seconds (Warm-up)
## Chain 1:                1.8264 seconds (Sampling)
## Chain 1:                3.60947 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 0.000176 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 1.76 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 2: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 2: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 2: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 2: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 2: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 2: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 2: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 2: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 2: Iteration:  1600 / 2000 [ 80%] (Sampling)

```

```

## Chain 2: Iteration: 1800 / 2000 [ 90%] (Sampling)
## Chain 2: Iteration: 2000 / 2000 [100%] (Sampling)
## Chain 2:
## Chain 2: Elapsed Time: 1.87932 seconds (Warm-up)
## Chain 2: 1.72235 seconds (Sampling)
## Chain 2: 3.60167 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 0.000121 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 1.21 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration: 1 / 2000 [ 0%] (Warmup)
## Chain 3: Iteration: 200 / 2000 [ 10%] (Warmup)
## Chain 3: Iteration: 400 / 2000 [ 20%] (Warmup)
## Chain 3: Iteration: 600 / 2000 [ 30%] (Warmup)
## Chain 3: Iteration: 800 / 2000 [ 40%] (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%] (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%] (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%] (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%] (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%] (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%] (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%] (Sampling)
## Chain 3:
## Chain 3: Elapsed Time: 1.84493 seconds (Warm-up)
## Chain 3: 1.90089 seconds (Sampling)
## Chain 3: 3.74582 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 0.000123 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 1.23 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration: 1 / 2000 [ 0%] (Warmup)
## Chain 4: Iteration: 200 / 2000 [ 10%] (Warmup)
## Chain 4: Iteration: 400 / 2000 [ 20%] (Warmup)
## Chain 4: Iteration: 600 / 2000 [ 30%] (Warmup)
## Chain 4: Iteration: 800 / 2000 [ 40%] (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%] (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%] (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%] (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%] (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%] (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%] (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%] (Sampling)
## Chain 4:
## Chain 4: Elapsed Time: 1.98334 seconds (Warm-up)

```

```
## Chain 4:          2.19197 seconds (Sampling)
## Chain 4:          4.17531 seconds (Total)
## Chain 4:
```

```
print(summary(M7))
```

```
## Family: bernoulli
## Links: mu = logit
## Formula: accuracy ~ cognate + (1 | subject) + diff
## Data: spa3 (Number of observations: 1187)
## Samples: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##          total post-warmup samples = 4000
##
## Group-Level Effects:
## ~subject (Number of levels: 27)
##          Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)      2.19      0.41      1.53      3.12 1.01      518      1376
##
## Population-Level Effects:
##          Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.91      0.51     -0.10      1.90 1.01      455      730
## cognate             1.17      0.18      0.82      1.54 1.00     2992     2743
## diff              -0.84      0.07     -0.99     -0.72 1.00     2509     2383
##
## Samples were drawn using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

```
M8 <- brm(accuracy~cognate+(1|subject)+diff,data=eng3,family=bernoulli,prior = c(set_prior("normal(0,8)
```

```
## Compiling Stan program...
```

```
## recompiling to avoid crashing R session
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
```

```
## clang -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.framework
```

```
## In file included from <built-in>:1:
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
```

```
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
```

```
## namespace Eigen {
```

```
## ^
```

```
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
```

```
## namespace Eigen {
```

```
## ^
```

```
## ;
```

```
## In file included from <built-in>:1:
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
```

```
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: f
```

```
## #include <complex>
```

```
## ^~~~~~
```

```
## 3 errors generated.
```

```
## make: *** [foo.o] Error 1
```



```

## Start sampling

##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 0.000155 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 1.55 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 1: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 1: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 1: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 1: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 1: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 1: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 1: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 1: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 1: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 1: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 1: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 1:
## Chain 1: Elapsed Time: 1.73979 seconds (Warm-up)
## Chain 1:                1.99043 seconds (Sampling)
## Chain 1:                3.73022 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 8.8e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.88 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 2: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 2: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 2: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 2: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 2: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 2: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 2: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 2: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 2: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 2: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 2: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 2:
## Chain 2: Elapsed Time: 2.04724 seconds (Warm-up)
## Chain 2:                2.21107 seconds (Sampling)
## Chain 2:                4.2583 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 3).

```

```

## Chain 3:
## Chain 3: Gradient evaluation took 0.000104 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 1.04 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 3: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 3: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 3: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 3: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 3: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 3: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 3: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 3: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 3: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 3: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 3: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 3:
## Chain 3: Elapsed Time: 1.86435 seconds (Warm-up)
## Chain 3:                1.45621 seconds (Sampling)
## Chain 3:                3.32056 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 9.7e-05 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.97 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 4: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 4: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 4: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 4: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 4: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 4: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 4: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 4: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 4: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 4: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 4: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 4:
## Chain 4: Elapsed Time: 2.07754 seconds (Warm-up)
## Chain 4:                2.09707 seconds (Sampling)
## Chain 4:                4.17461 seconds (Total)
## Chain 4:

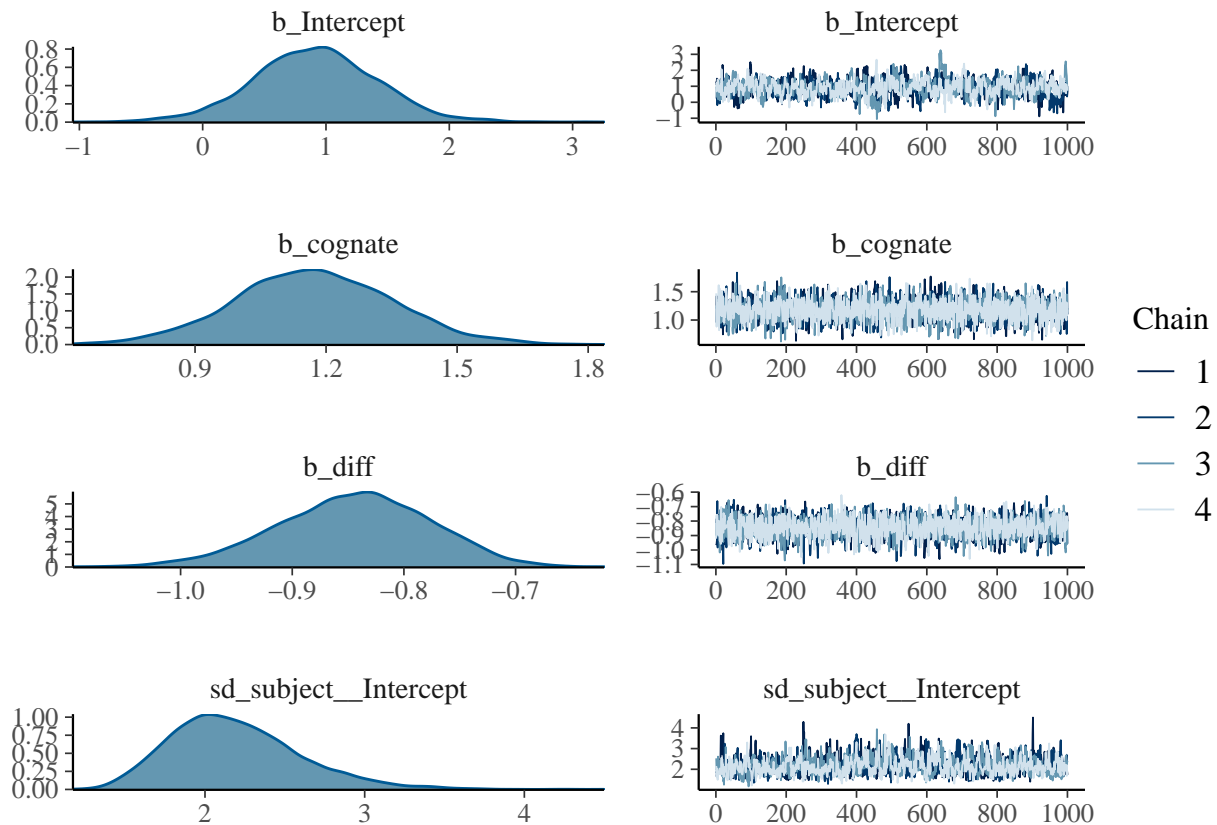
## Warning: Bulk Effective Samples Size (ESS) is too low, indicating posterior means and medians may be
## Running the chains for more iterations may help. See
## http://mc-stan.org/misc/warnings.html#bulk-ess

```

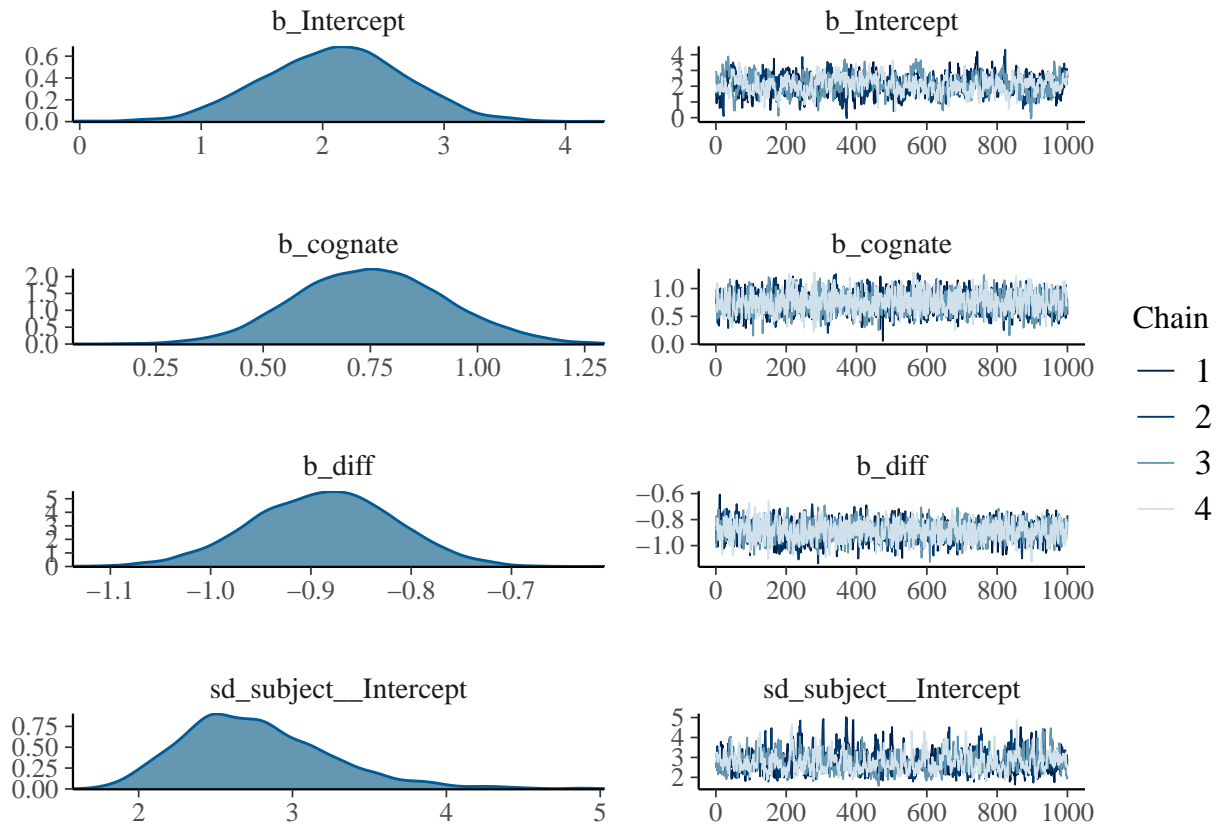
```
print(summary(M8))
```

```
## Family: bernoulli
## Links: mu = logit
## Formula: accuracy ~ cognate + (1 | subject) + diff
## Data: eng3 (Number of observations: 1188)
## Samples: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##           total post-warmup samples = 4000
##
## Group-Level Effects:
## ~subject (Number of levels: 27)
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)    2.76      0.48      2.00      3.88 1.00      579      1163
##
## Population-Level Effects:
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept        2.10      0.58      0.98      3.19 1.01      394      696
## cognate           0.75      0.17      0.42      1.10 1.00     2277     2575
## diff             -0.89      0.07     -1.03     -0.75 1.00     2790     2834
##
## Samples were drawn using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

```
plot(M7)
```



```
plot(M8)
```



Adding L2AoA predictor.

L2:nonnative language AoA: age of acquisition

```
M9<- brm(accuracy~cognate+(1|subject)+diff+L2AoA,data=spa3,family=bernoulli,prior = c(set_prior("normal",
## Warning: Rows containing NAs were excluded from the model.
## Compiling Stan program...
## recompiling to avoid crashing R session
## Trying to compile a simple C file
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## clang -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.framework
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/include
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
## namespace Eigen {
## ^
## ;
## In file included from <built-in>:1:
```

```

## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: f
## #include <complex>
##      ~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1

## Start sampling

##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 0.000148 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 1.48 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 1: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 1: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 1: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 1: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 1: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 1: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 1: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 1: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 1: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 1: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 1: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 1:
## Chain 1: Elapsed Time: 3.53265 seconds (Warm-up)
## Chain 1:                2.51202 seconds (Sampling)
## Chain 1:                6.04467 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 9.3e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.93 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 2: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 2: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 2: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 2: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 2: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 2: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 2: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 2: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 2: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 2: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 2: Iteration:  2000 / 2000 [100%] (Sampling)

```

```

## Chain 2:
## Chain 2: Elapsed Time: 3.4702 seconds (Warm-up)
## Chain 2: 2.73533 seconds (Sampling)
## Chain 2: 6.20553 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 0.000101 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 1.01 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration: 1 / 2000 [ 0%] (Warmup)
## Chain 3: Iteration: 200 / 2000 [ 10%] (Warmup)
## Chain 3: Iteration: 400 / 2000 [ 20%] (Warmup)
## Chain 3: Iteration: 600 / 2000 [ 30%] (Warmup)
## Chain 3: Iteration: 800 / 2000 [ 40%] (Warmup)
## Chain 3: Iteration: 1000 / 2000 [ 50%] (Warmup)
## Chain 3: Iteration: 1001 / 2000 [ 50%] (Sampling)
## Chain 3: Iteration: 1200 / 2000 [ 60%] (Sampling)
## Chain 3: Iteration: 1400 / 2000 [ 70%] (Sampling)
## Chain 3: Iteration: 1600 / 2000 [ 80%] (Sampling)
## Chain 3: Iteration: 1800 / 2000 [ 90%] (Sampling)
## Chain 3: Iteration: 2000 / 2000 [100%] (Sampling)
## Chain 3:
## Chain 3: Elapsed Time: 3.29152 seconds (Warm-up)
## Chain 3: 2.97193 seconds (Sampling)
## Chain 3: 6.26345 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 9.4e-05 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.94 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration: 1 / 2000 [ 0%] (Warmup)
## Chain 4: Iteration: 200 / 2000 [ 10%] (Warmup)
## Chain 4: Iteration: 400 / 2000 [ 20%] (Warmup)
## Chain 4: Iteration: 600 / 2000 [ 30%] (Warmup)
## Chain 4: Iteration: 800 / 2000 [ 40%] (Warmup)
## Chain 4: Iteration: 1000 / 2000 [ 50%] (Warmup)
## Chain 4: Iteration: 1001 / 2000 [ 50%] (Sampling)
## Chain 4: Iteration: 1200 / 2000 [ 60%] (Sampling)
## Chain 4: Iteration: 1400 / 2000 [ 70%] (Sampling)
## Chain 4: Iteration: 1600 / 2000 [ 80%] (Sampling)
## Chain 4: Iteration: 1800 / 2000 [ 90%] (Sampling)
## Chain 4: Iteration: 2000 / 2000 [100%] (Sampling)
## Chain 4:
## Chain 4: Elapsed Time: 3.58309 seconds (Warm-up)
## Chain 4: 2.50543 seconds (Sampling)
## Chain 4: 6.08853 seconds (Total)

```

```
## Chain 4:
```

```
print(summary(M9))
```

```
## Family: bernoulli
## Links: mu = logit
## Formula: accuracy ~ cognate + (1 | subject) + diff + L2AoA
## Data: spa3 (Number of observations: 1187)
## Samples: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##           total post-warmup samples = 4000
##
## Group-Level Effects:
## ~subject (Number of levels: 27)
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)      2.18      0.41      1.53      3.13 1.01      729      1417
##
## Population-Level Effects:
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.11      0.81     -1.48      1.61 1.00      766      1273
## cognate             1.17      0.18      0.84      1.55 1.00      3392      2720
## diff              -0.84      0.07     -0.98     -0.71 1.00      3358      2813
## L2AoA               0.07      0.06     -0.04      0.19 1.01      851      1110
##
## Samples were drawn using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

```
M10 <- brm(accuracy~cognate+(1|subject)+diff+L2AoA,data=eng3,family=bernoulli,prior = c(set_prior("norm
```

```
## Compiling Stan program...
```

```
## recompiling to avoid crashing R session
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## clang -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.framework/Resources/include" -c foo.c -o foo.o
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/include/StanHeaders/StanHeaders.hpp:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: fatal error: 'complex' file not found
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: fatal error: 'complex' file not found
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: fatal error: 'complex' file not found
## namespace Eigen {
## ^
## ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/include/StanHeaders/StanHeaders.hpp:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: fatal error: 'complex' file not found
## #include <complex>
## ~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1
```

```

## Start sampling

##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 0.000216 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 2.16 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 1: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 1: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 1: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 1: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 1: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 1: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 1: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 1: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 1: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 1: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 1: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 1:
## Chain 1: Elapsed Time: 2.8227 seconds (Warm-up)
## Chain 1:                1.93841 seconds (Sampling)
## Chain 1:                4.76111 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 9.1e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.91 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 2: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 2: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 2: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 2: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 2: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 2: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 2: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 2: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 2: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 2: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 2: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 2:
## Chain 2: Elapsed Time: 2.96983 seconds (Warm-up)
## Chain 2:                2.34323 seconds (Sampling)
## Chain 2:                5.31306 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 3).

```



```

## Chain 3:
## Chain 3: Gradient evaluation took 9.1e-05 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.91 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 3: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 3: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 3: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 3: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 3: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 3: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 3: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 3: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 3: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 3: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 3: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 3:
## Chain 3: Elapsed Time: 3.07304 seconds (Warm-up)
## Chain 3:                1.9468 seconds (Sampling)
## Chain 3:                5.01984 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 9.5e-05 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 0.95 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 4: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 4: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 4: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 4: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 4: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 4: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 4: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 4: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 4: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 4: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 4: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 4:
## Chain 4: Elapsed Time: 2.95493 seconds (Warm-up)
## Chain 4:                1.73541 seconds (Sampling)
## Chain 4:                4.69035 seconds (Total)
## Chain 4:

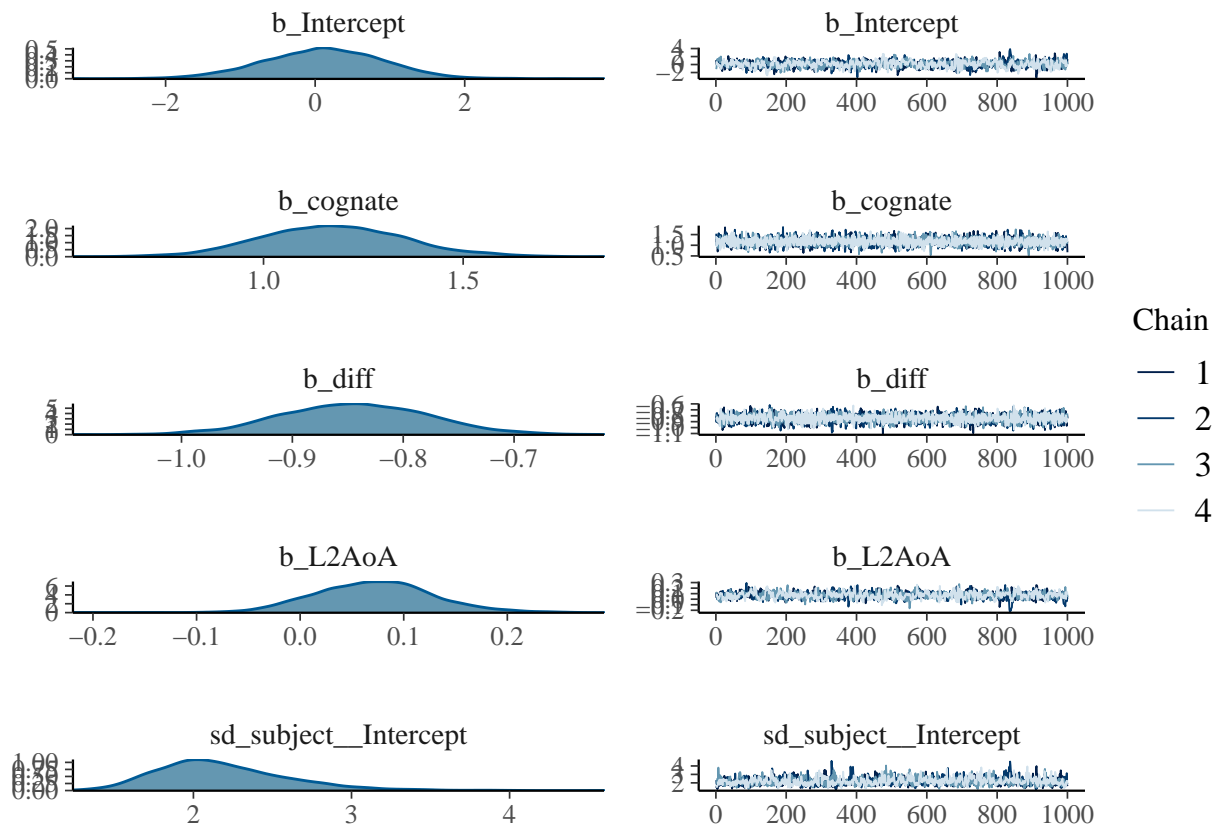
## Warning: Bulk Effective Samples Size (ESS) is too low, indicating posterior means and medians may be
## Running the chains for more iterations may help. See
## http://mc-stan.org/misc/warnings.html#bulk-ess

```

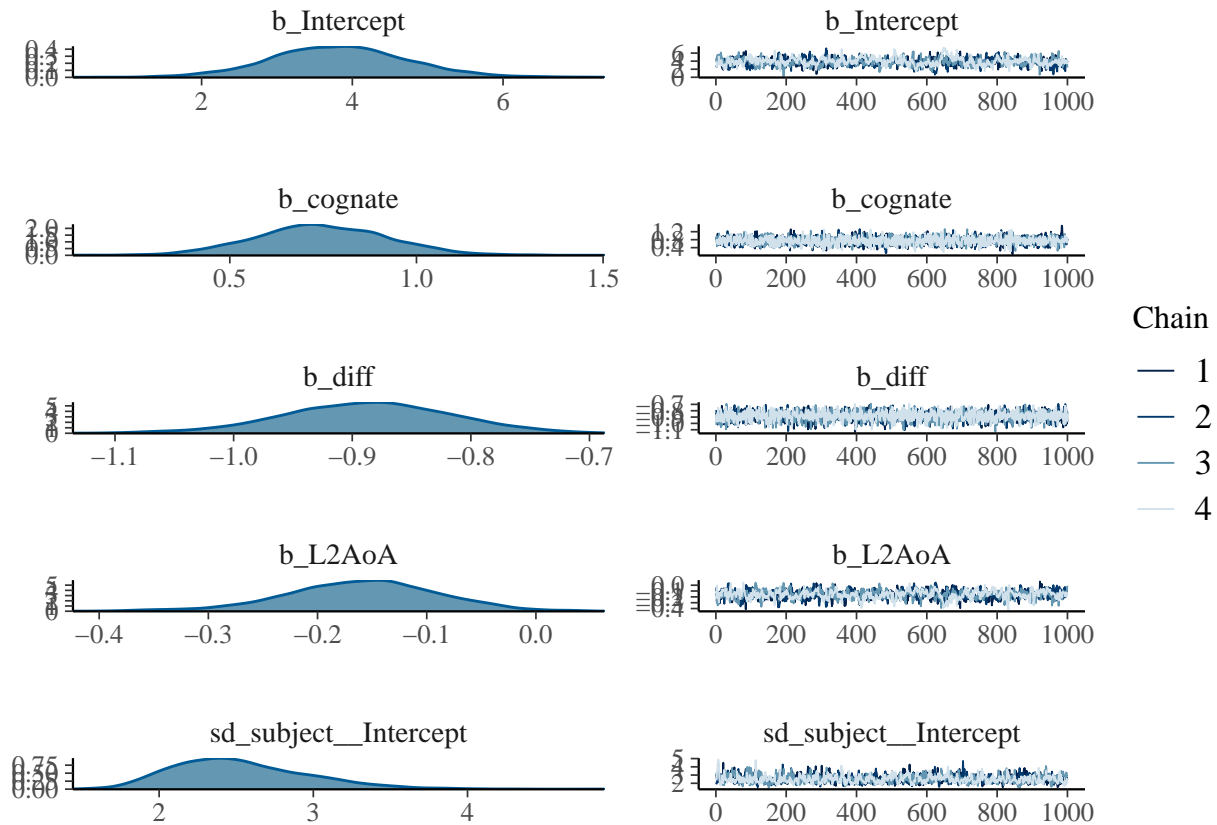
```
print(summary(M10))
```

```
## Family: bernoulli
## Links: mu = logit
## Formula: accuracy ~ cognate + (1 | subject) + diff + L2AoA
## Data: eng3 (Number of observations: 1188)
## Samples: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##           total post-warmup samples = 4000
##
## Group-Level Effects:
## ~subject (Number of levels: 27)
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)      2.53      0.44      1.83      3.51 1.00      780      1660
##
## Population-Level Effects:
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          3.82      0.92      2.06      5.66 1.01      369      1002
## cognate             0.75      0.18      0.40      1.09 1.00      2675      2426
## diff              -0.89      0.07     -1.03     -0.75 1.00      2991      3072
## L2AoA             -0.16      0.07     -0.31     -0.03 1.01      634      1156
##
## Samples were drawn using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

```
plot(M9)
```



```
plot(M10)
```



Revision: may need to include language: language=0: spanish as L1 native language; english nonnative
language=1: english as L1 native language;spanish nonnative

```
M9<- brm(accuracy~cognate+(1|subject)+diff+L2AoA+Language,data=spa3,family=bernoulli,prior = c(set_prior
```

```
## Warning: Rows containing NAs were excluded from the model.
```

```
## Compiling Stan program...
```

```
## recompiling to avoid crashing R session
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
```

```
## clang -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.framework
```

```
## In file included from <built-in>:1:
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
```

```
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
```

```
## namespace Eigen {
```

```
## ~
```

```
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
```

```
## namespace Eigen {
```

```
## ~
```

```
## ;
```

```
## In file included from <built-in>:1:
```

```
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc
```

```

## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: f
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: f
## #include <complex>
##      ~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1

## Start sampling

##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 0.000171 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 1.71 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 1: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 1: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 1: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 1: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 1: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 1: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 1: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 1: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 1: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 1: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 1: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 1:
## Chain 1: Elapsed Time: 4.23269 seconds (Warm-up)
## Chain 1:                3.14661 seconds (Sampling)
## Chain 1:                7.3793 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 9.2e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.92 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 2: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 2: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 2: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 2: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 2: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 2: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 2: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 2: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 2: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 2: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 2: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 2:

```

```

## Chain 2: Elapsed Time: 4.47628 seconds (Warm-up)
## Chain 2:          2.59091 seconds (Sampling)
## Chain 2:          7.06718 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 3).
## Chain 3:
## Chain 3: Gradient evaluation took 9.5e-05 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.95 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 3: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 3: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 3: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 3: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 3: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 3: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 3: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 3: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 3: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 3: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 3: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 3:
## Chain 3: Elapsed Time: 4.1845 seconds (Warm-up)
## Chain 3:          2.98475 seconds (Sampling)
## Chain 3:          7.16924 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 0.000116 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 1.16 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 4: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 4: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 4: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 4: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 4: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 4: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 4: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 4: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 4: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 4: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 4: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 4:
## Chain 4: Elapsed Time: 3.95596 seconds (Warm-up)
## Chain 4:          2.74471 seconds (Sampling)
## Chain 4:          6.70067 seconds (Total)
## Chain 4:

```

```
print(summary(M9))
```

```
## Family: bernoulli
## Links: mu = logit
## Formula: accuracy ~ cognate + (1 | subject) + diff + L2AoA + Language
## Data: spa3 (Number of observations: 1187)
## Samples: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##           total post-warmup samples = 4000
##
## Group-Level Effects:
## ~subject (Number of levels: 27)
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)      2.17      0.43      1.49      3.19 1.00      1001      1723
##
## Population-Level Effects:
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          0.66      0.85     -1.03      2.41 1.00        904      1435
## cognate             1.18      0.18      0.83      1.53 1.00       3798      2723
## diff               -0.85      0.07     -0.99     -0.72 1.00       3494      2471
## L2AoA               0.05      0.06     -0.06      0.17 1.00       1005      1765
## Language           -1.62      1.14     -3.91      0.55 1.00       1163      1658
##
## Samples were drawn using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

```
M10 <- brm(accuracy~cognate+(1|subject)+diff+L2AoA+Language,data=eng3,family=bernoulli,prior = c(set_pr
```

```
## Compiling Stan program...
```

```
## recompiling to avoid crashing R session
```

```
## Trying to compile a simple C file
```

```
## Running /Library/Frameworks/R.framework/Resources/bin/R CMD SHLIB foo.c
## clang -I"/Library/Frameworks/R.framework/Resources/include" -DNDEBUG -I"/Library/Frameworks/R.framework
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
## namespace Eigen {
## ^
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/src/Core/util
## namespace Eigen {
## ^
## ;
## In file included from <built-in>:1:
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/StanHeaders/inc
## In file included from /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/inclu
## /Library/Frameworks/R.framework/Versions/4.0/Resources/library/RcppEigen/include/Eigen/Core:96:10: f
## #include <complex>
## ^~~~~~
## 3 errors generated.
## make: *** [foo.o] Error 1
```

```

## Start sampling

##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 1).
## Chain 1:
## Chain 1: Gradient evaluation took 0.000349 seconds
## Chain 1: 1000 transitions using 10 leapfrog steps per transition would take 3.49 seconds.
## Chain 1: Adjust your expectations accordingly!
## Chain 1:
## Chain 1:
## Chain 1: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 1: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 1: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 1: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 1: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 1: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 1: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 1: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 1: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 1: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 1: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 1: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 1:
## Chain 1: Elapsed Time: 4.18633 seconds (Warm-up)
## Chain 1:                3.23836 seconds (Sampling)
## Chain 1:                7.42469 seconds (Total)
## Chain 1:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 2).
## Chain 2:
## Chain 2: Gradient evaluation took 9.9e-05 seconds
## Chain 2: 1000 transitions using 10 leapfrog steps per transition would take 0.99 seconds.
## Chain 2: Adjust your expectations accordingly!
## Chain 2:
## Chain 2:
## Chain 2: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 2: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 2: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 2: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 2: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 2: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 2: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 2: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 2: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 2: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 2: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 2: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 2:
## Chain 2: Elapsed Time: 4.21154 seconds (Warm-up)
## Chain 2:                3.14356 seconds (Sampling)
## Chain 2:                7.35509 seconds (Total)
## Chain 2:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 3).

```

```

## Chain 3:
## Chain 3: Gradient evaluation took 9.3e-05 seconds
## Chain 3: 1000 transitions using 10 leapfrog steps per transition would take 0.93 seconds.
## Chain 3: Adjust your expectations accordingly!
## Chain 3:
## Chain 3:
## Chain 3: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 3: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 3: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 3: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 3: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 3: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 3: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 3: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 3: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 3: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 3: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 3: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 3:
## Chain 3: Elapsed Time: 4.40935 seconds (Warm-up)
## Chain 3:                3.82159 seconds (Sampling)
## Chain 3:                8.23095 seconds (Total)
## Chain 3:
##
## SAMPLING FOR MODEL 'fecdb0ea2e3aab30d18291906b136a6d' NOW (CHAIN 4).
## Chain 4:
## Chain 4: Gradient evaluation took 0.00011 seconds
## Chain 4: 1000 transitions using 10 leapfrog steps per transition would take 1.1 seconds.
## Chain 4: Adjust your expectations accordingly!
## Chain 4:
## Chain 4:
## Chain 4: Iteration:    1 / 2000 [  0%] (Warmup)
## Chain 4: Iteration:   200 / 2000 [ 10%] (Warmup)
## Chain 4: Iteration:   400 / 2000 [ 20%] (Warmup)
## Chain 4: Iteration:   600 / 2000 [ 30%] (Warmup)
## Chain 4: Iteration:   800 / 2000 [ 40%] (Warmup)
## Chain 4: Iteration:  1000 / 2000 [ 50%] (Warmup)
## Chain 4: Iteration:  1001 / 2000 [ 50%] (Sampling)
## Chain 4: Iteration:  1200 / 2000 [ 60%] (Sampling)
## Chain 4: Iteration:  1400 / 2000 [ 70%] (Sampling)
## Chain 4: Iteration:  1600 / 2000 [ 80%] (Sampling)
## Chain 4: Iteration:  1800 / 2000 [ 90%] (Sampling)
## Chain 4: Iteration:  2000 / 2000 [100%] (Sampling)
## Chain 4:
## Chain 4: Elapsed Time: 4.23972 seconds (Warm-up)
## Chain 4:                3.81257 seconds (Sampling)
## Chain 4:                8.05229 seconds (Total)
## Chain 4:
print(summary(M10))

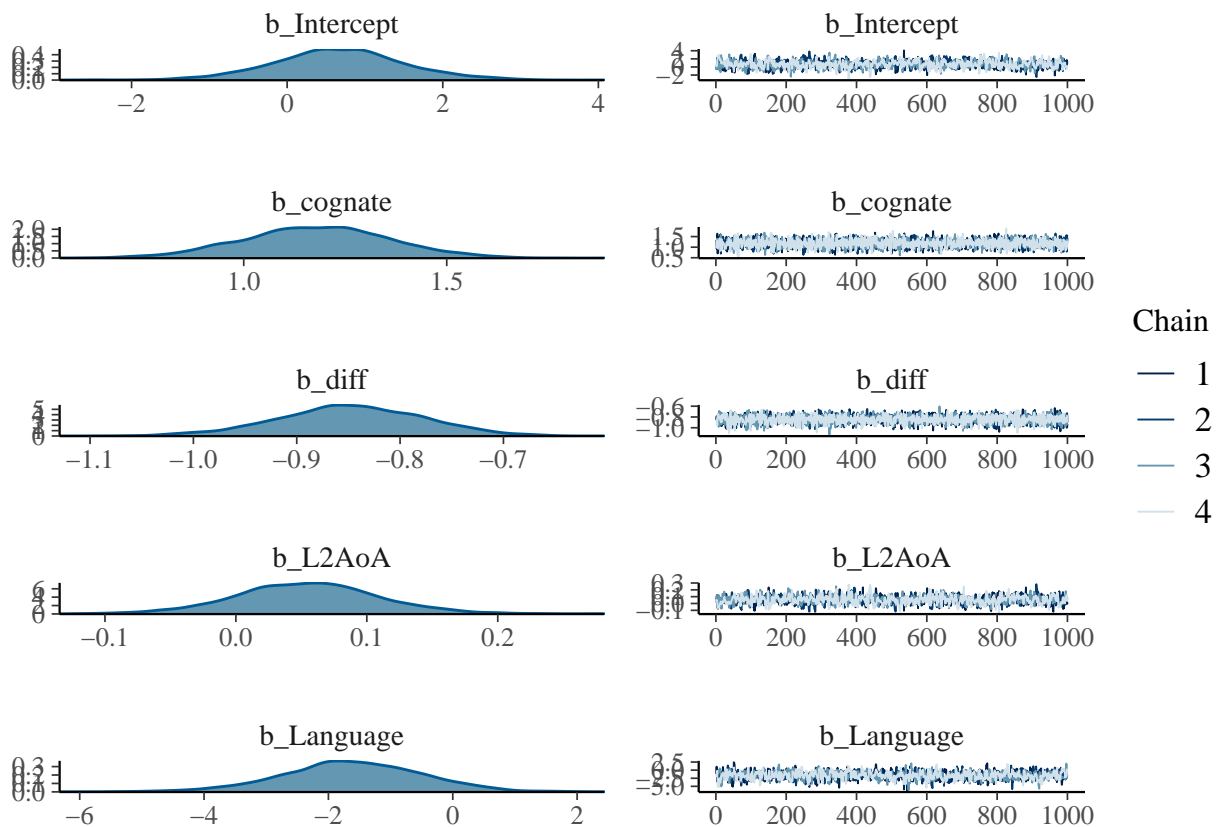
## Family: bernoulli
## Links: mu = logit
## Formula: accuracy ~ cognate + (1 | subject) + diff + L2AoA + Language
## Data: eng3 (Number of observations: 1188)

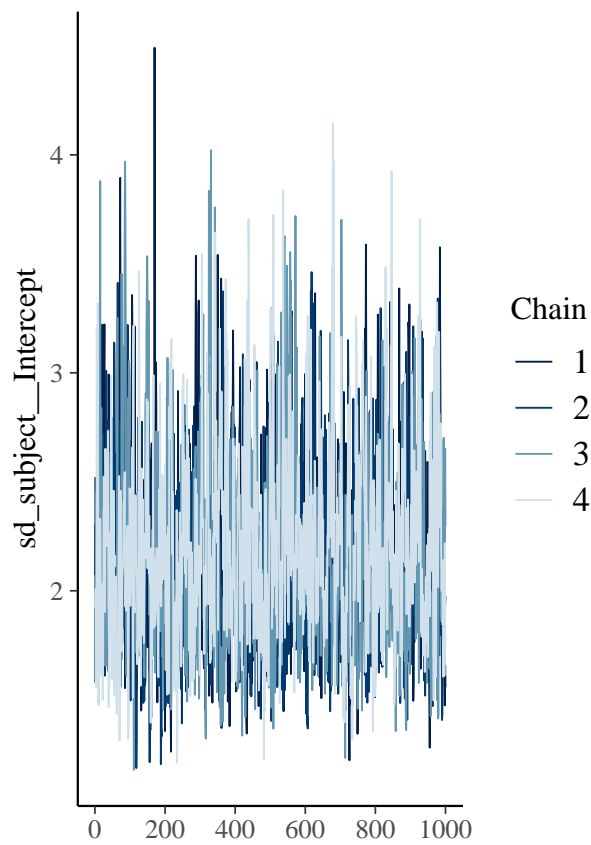
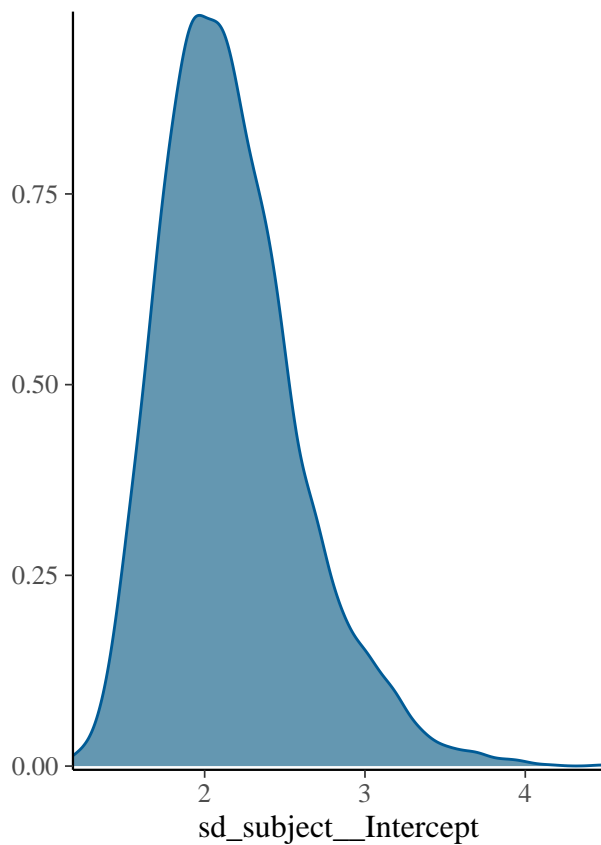
```



```
## Samples: 4 chains, each with iter = 2000; warmup = 1000; thin = 1;
##           total post-warmup samples = 4000
##
## Group-Level Effects:
## ~subject (Number of levels: 27)
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## sd(Intercept)      2.54      0.45      1.84      3.59 1.00      931      1931
##
## Population-Level Effects:
##           Estimate Est.Error 1-95% CI u-95% CI Rhat Bulk_ESS Tail_ESS
## Intercept          4.11       1.08      2.03      6.30 1.00      1156      1786
## cognate             0.76       0.18      0.42      1.10 1.00      3971      2925
## diff              -0.89       0.07     -1.03     -0.75 1.00      3732      3064
## L2AoA              -0.17       0.07     -0.32     -0.03 1.01      1350      1716
## Language           -0.90       1.26     -3.46      1.64 1.00      1258      1687
##
## Samples were drawn using sampling(NUTS). For each parameter, Bulk_ESS
## and Tail_ESS are effective sample size measures, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

plot(M9)





`plot(M10)`

