

Supplementary Materials

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Frequentist Covariate Models

N400

Comparison of Additive and Multiplicative Models

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
Additive Model	15	6959	7049	-3465	6929			
Interaction with condition	17	6960	7061	-3463	6926	4	2	0.17
All interactions	20	6964	7083	-3462	6924	2	3	0.54

Comparison of Basic and Overlap Models

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
Basic Model	14	7002	7086	-3487	6974			
P300 covariate	15	6959	7049	-3465	6929	45	1	< 0.001

Summary of Best Additive Overlap Model

```
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: scale(n400) ~ 1 + scale(p300) + scale(baseline) * cond + (1 +
cond | subj) + (1 | item)
## Data: eeg.cp
## Control: lmerControl(optimizer = "bobyqa", calc.derivs = FALSE)
##
##      AIC      BIC   logLik deviance df.resid
## 6959.3  7048.8 -3464.6   6929.3     2883
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.0298 -0.6538  0.0309  0.6448  5.0190
##
## Random effects:
## Groups   Name                Variance Std.Dev. Corr
## item    (Intercept)          0.01707  0.1306
## subj    (Intercept)          0.08434  0.2904
##          condrelated > antonym 0.13423  0.3664 -0.35
##          condunrelated > related 0.01242  0.1114  0.52  0.62
## Residual                    0.60441  0.7774
## Number of obs: 2898, groups:  item, 80; subj, 20
##
## Fixed effects:
```

```

##                               Estimate Std. Error t value
## (Intercept)                   -0.125417   0.068343  -1.835
## scale(p300)                    0.109787   0.016175   6.788
## scale(baseline)                 -0.178207   0.017319 -10.290
## condrelated > antonym           -0.495278   0.089720  -5.520
## condunrelated > related         -0.325061   0.048261  -6.735
## scale(baseline):condrelated > antonym  0.050135   0.038768   1.293
## scale(baseline):condunrelated > related 0.002496   0.043327   0.058
##
## Correlation of Fixed Effects:
##      (Intr) s(300) scl(b) cndr>a cndn>r s():>a
## scale(p300)  0.021
## scale(bsln) -0.014 -0.078
## cndrltd>ant -0.282  0.085 -0.009
## cndnrltd>rl  0.254 -0.014 -0.084  0.092
## scl(bsl):>a -0.005 -0.043  0.308  0.013 -0.018
## scl(bsl):>r -0.020  0.009 -0.015 -0.004 -0.069 -0.562

```

P300

Comparison of Additive and Multiplicative Models

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
Additive Model	15	7696	7785	-3833	7666			
Interaction with condition	17	7696	7798	-3831	7662	4	0.17	0.61
All interactions	20	7698	7817	-3829	7658	4	0.24	0.62

Comparison of Basic and Overlap Models

	Df	AIC	BIC	logLik	deviance	Chisq	Chi Df	Pr(>Chisq)
Basic Model	14	7743	7827	-3858	7715			
N400 covariate	15	7996	7785	-3833	7666	50	1	< 0.001

Summary of Best Additive Overlap Model

```

## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: scale(p300) ~ 1 + scale(n400) + scale(baseline) * cond + (1 + cond | subj) + (1 | item)
## Data: eeg.cp
## Control: lmerControl(optimizer = "bobyqa", calc.derivs = FALSE)
##
##      AIC      BIC  logLik deviance df.resid
## 7695.6  7785.1 -3832.8  7665.6     2883

```

```

##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -4.3940 -0.6410 -0.0249  0.6495  3.5622
##
## Random effects:
##   Groups   Name                Variance Std.Dev. Corr
##   item     (Intercept)          0.007636 0.08739
##   subj     (Intercept)          0.052825 0.22984
##           condrelated > antonym 0.191659 0.43779 -0.07
##           condunrelated > related 0.007160 0.08462 -0.98  0.25
## Residual                                0.791877 0.88987
## Number of obs: 2898, groups:  item, 80; subj, 20
##
## Fixed effects:
##                                Estimate Std. Error t value
## (Intercept)                    -0.06911   0.05528   -1.250
## scale(n400)                     0.14848   0.02080    7.138
## scale(baseline)                  0.11383   0.01990    5.719
## condrelated > antonym            -0.38928   0.10674   -3.647
## condunrelated > related           0.09003   0.05134    1.754
## scale(baseline):condrelated > antonym 0.09800   0.04508    2.174
## scale(baseline):condunrelated > related -0.02019   0.04923   -0.410
##
## Correlation of Fixed Effects:
##      (Intr) s(400) scl(b) cndr>a cndn>r s():>a
## scale(n400)  0.051
## scale(bsln) -0.007  0.172
## cndrltd>ant -0.020  0.107  0.016
## cndnrltd>rl -0.331  0.128 -0.063 -0.105
## scl(bsl):>a -0.007 -0.029  0.324  0.012 -0.024
## scl(bsl):>r -0.027 -0.002 -0.073 -0.005 -0.069 -0.585

```

Bayesian Modelling of ERP data

Model Summary

```
## Family: MV(gaussian, gaussian)
## Links: mu = identity; sigma = identity
##          mu = identity; sigma = identity
## Formula: scale(p300) ~ 1 + scale(baseline) * cond + (1 + cond | p | subj) + (1 | q | item)
##          scale(n400) ~ 1 + scale(baseline) * cond + (1 + cond | p | subj) + (1 | q | item)
## Data: eeg.cp (Number of observations: 2898)
## Samples: 4 chains, each with iter = 10000; warmup = 1000; thin = 3;
##          total post-warmup samples = 12000
##
## Group-Level Effects:
## ~item (Number of levels: 80)
##
##          Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
## sd(scalep300_Intercept)          0.12    0.02    0.07    0.16     9931 1.00
## sd(scalen400_Intercept)          0.15    0.02    0.11    0.19    10083 1.00
## cor(scalep300_Intercept,scalen400_Intercept) 0.84    0.13    0.52    0.99     7054 1.00
##
## ~subj (Number of levels: 20)
##
##          Estimate Est.Error l-95% CI u-95% CI Eff.Sample Rhat
## sd(scalep300_Intercept)          0.28    0.05    0.19    0.41     9218 1.00
## sd(scalep300_condrelated>antonym) 0.54    0.11    0.36    0.79     9991 1.00
## sd(scalep300_condunrelated>related) 0.12    0.07    0.01    0.28     7900 1.00
## sd(scalen400_Intercept)          0.35    0.06    0.25    0.49    11047 1.00
## sd(scalen400_condrelated>antonym) 0.46    0.09    0.30    0.67    11377 1.00
## sd(scalen400_condunrelated>related) 0.13    0.06    0.01    0.26     9248 1.00
## cor(scalep300_Intercept,scalep300_condrelated>antonym) -0.11    0.22   -0.51    0.32     9033 1.00
## cor(scalep300_Intercept,scalep300_condunrelated>related) -0.28    0.32   -0.80    0.44    13086 1.00
## cor(scalep300_condrelated>antonym,scalep300_condunrelated>related) 0.08    0.33   -0.56    0.69    12515 1.00
## cor(scalep300_Intercept,scalen400_Intercept) 0.33    0.20   -0.10    0.67    11928 1.00
## cor(scalep300_condrelated>antonym,scalen400_Intercept) -0.32    0.20   -0.67    0.10    10882 1.00
## cor(scalep300_condunrelated>related,scalen400_Intercept) -0.08    0.32   -0.67    0.56     5739 1.00
## cor(scalep300_Intercept,scalen400_condrelated>antonym) -0.10    0.22   -0.52    0.34    12131 1.00
## cor(scalep300_condrelated>antonym,scalen400_condrelated>antonym) 0.17    0.22   -0.29    0.58    11243 1.00
## cor(scalep300_condunrelated>related,scalen400_condrelated>antonym) 0.23    0.33   -0.47    0.78     5027 1.00
## cor(scalen400_Intercept,scalen400_condrelated>antonym) -0.25    0.21   -0.63    0.19    12173 1.00
## cor(scalep300_Intercept,scalen400_condunrelated>related) -0.25    0.30   -0.76    0.39    12157 1.00
## cor(scalep300_condrelated>antonym,scalen400_condunrelated>related) 0.12    0.30   -0.50    0.67    12328 1.00
## cor(scalep300_condunrelated>related,scalen400_condunrelated>related) 0.30    0.35   -0.48    0.85     7305 1.00
## cor(scalen400_Intercept,scalen400_condunrelated>related) 0.20    0.29   -0.42    0.71    12156 1.00
```

```
## cor(scalen400_condrelated>antonym,scalen400_condunrelated>related)      0.27      0.29      -0.35      0.77      11270 1.00
```

```
##
```

```
## Population-Level Effects:
```

```
##           Estimate Est.Error 1-95% CI u-95% CI Eff.Sample Rhat
## scalep300_Intercept      -0.09      0.07   -0.23    0.05     8097 1.00
## scalen400_Intercept      -0.14      0.08   -0.29    0.03    10574 1.00
## scalep300_scalebaseline    0.09      0.02    0.05    0.13    12146 1.00
## scalep300_condrelated>antonym -0.47      0.13   -0.72   -0.21     8365 1.00
## scalep300_condunrelated>related  0.04      0.06   -0.07    0.16    12253 1.00
## scalep300_scalebaseline:condrelated>antonym  0.11      0.05    0.02    0.20    12468 1.00
## scalep300_scalebaseline:condunrelated>related -0.03      0.05   -0.13    0.07    11903 1.00
## scalen400_scalebaseline   -0.17      0.02   -0.20   -0.13    13731 1.00
## scalen400_condrelated>antonym -0.55      0.11   -0.77   -0.33    11015 1.00
## scalen400_condunrelated>related -0.32      0.05   -0.42   -0.21    11969 1.00
## scalen400_scalebaseline:condrelated>antonym  0.07      0.04   -0.01    0.15    12327 1.00
## scalen400_scalebaseline:condunrelated>related -0.01      0.05   -0.10    0.08    11951 1.00
```

```
##
```

```
## Family Specific Parameters:
```

```
##           Estimate Est.Error 1-95% CI u-95% CI Eff.Sample Rhat
## sigma_scalep300      0.90      0.01    0.87    0.92    13693 1.00
## sigma_scalen400      0.78      0.01    0.76    0.80    12957 1.00
```

```
##
```

```
## Residual Correlations:
```

```
##           Estimate Est.Error 1-95% CI u-95% CI Eff.Sample Rhat
## rescor(scalep300,scalen400)  0.11      0.02    0.08    0.15    13432 1.00
```

```
##
```

```
## Samples were drawn using sampling(NUTS). For each parameter, Eff.Sample
## is a crude measure of effective sample size, and Rhat is the potential
## scale reduction factor on split chains (at convergence, Rhat = 1).
```

Correlations across Response Variables

Random Effects

```
sign(VarCorr(eeg.mvmodel)[["subj"]]$cor[1:3,"Q2.5",4:6]) !=
sign(VarCorr(eeg.mvmodel)[["subj"]]$cor[1:3,"Q97.5",4:6])
```

	scalen400_Intercept	scalen400_condantonym	scalen400_condrelated
scalep300_Intercept	TRUE	TRUE	TRUE
scalep300_condantonym	TRUE	TRUE	TRUE
scalep300_condrelated	TRUE	TRUE	TRUE

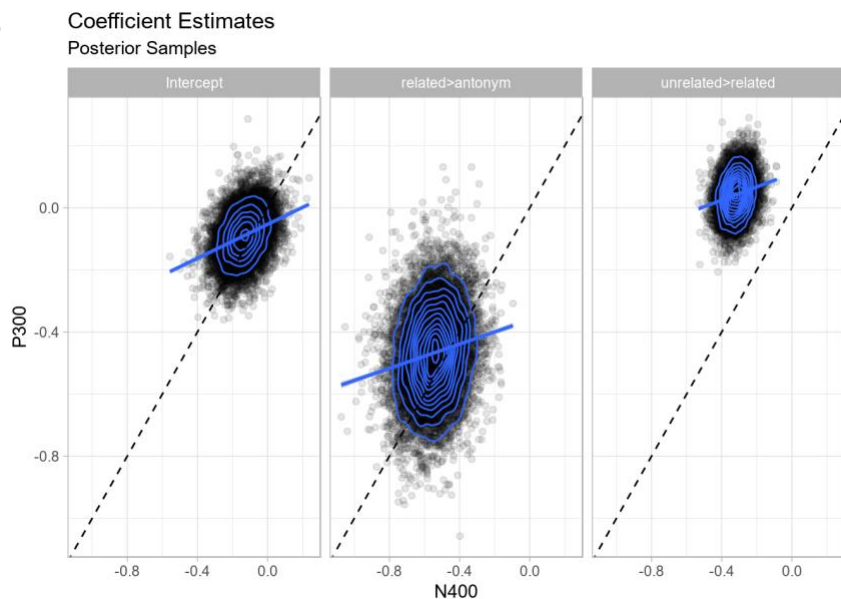
Residuals

```
VarCorr(eeg.mvmodel)[["residual__"]]$cor["scalen400",,"scalep300"]
## Estimate Est.Error Q2.5 Q97.5
## 0.11348675 0.01869162 0.07663292 0.14996596
hdi(VarCorr(eeg.mvmodel,summary=FALSE)[["residual__"]]$cor[, "scalen400", "scalep300"]
)
## lower upper
## 0.07816224 0.15119537
## attr("credMass")
## [1] 0.95
```

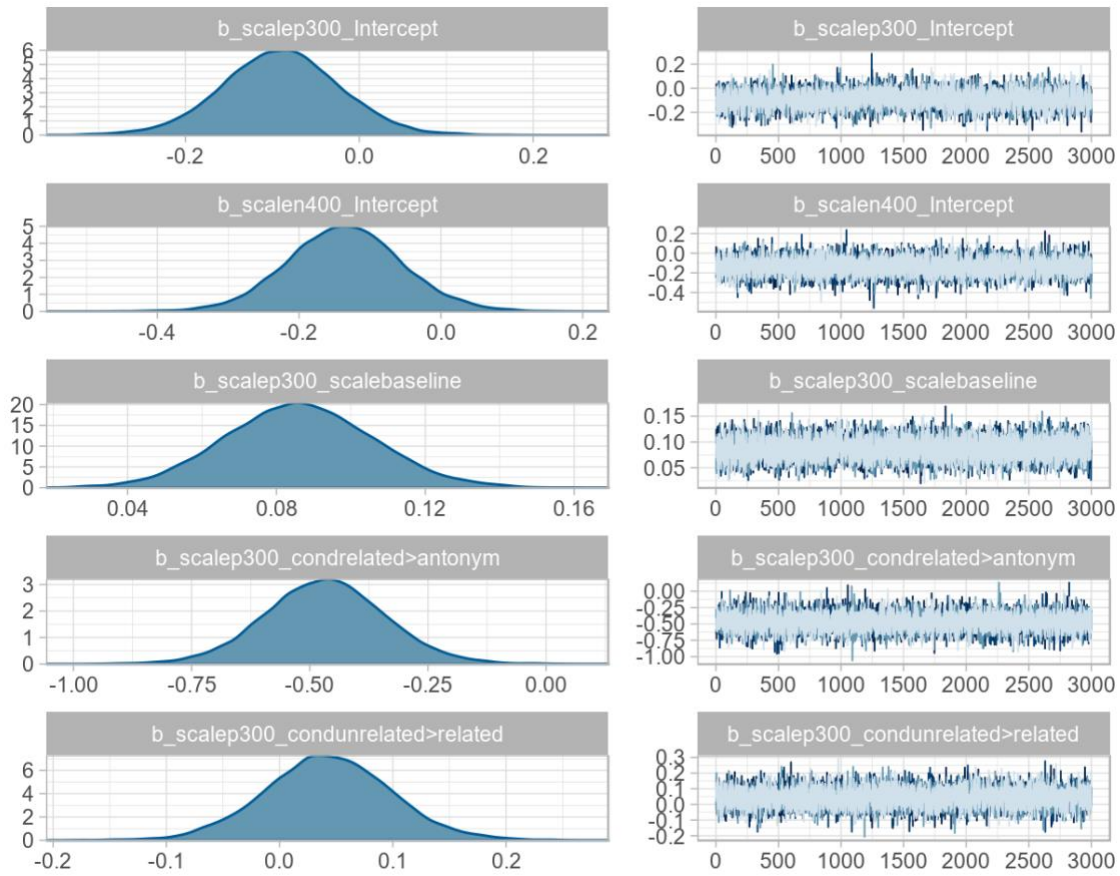
Fixed effects

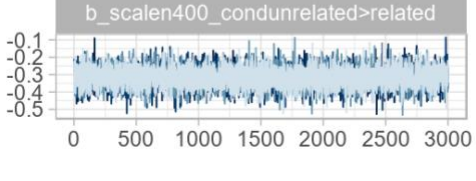
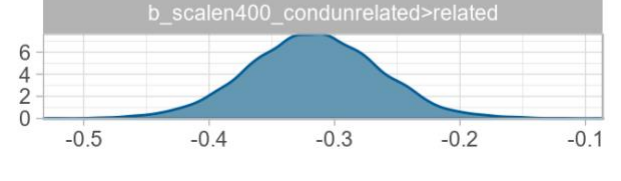
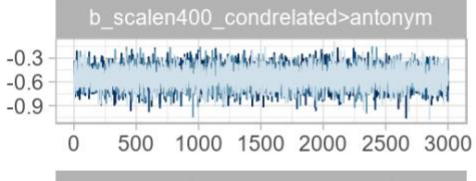
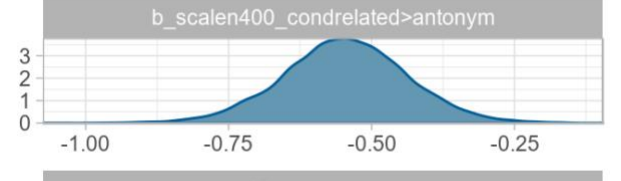
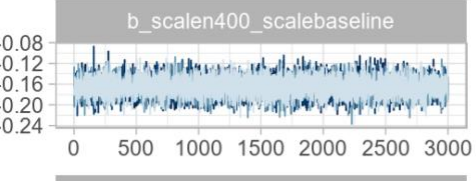
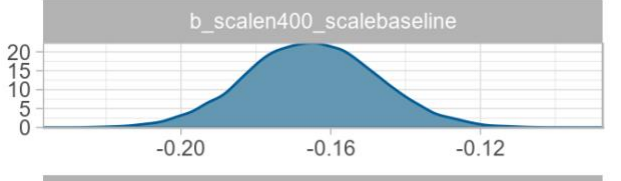
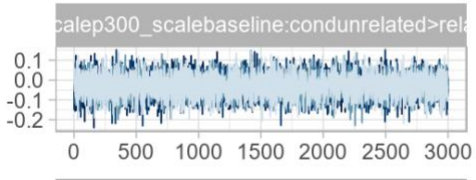
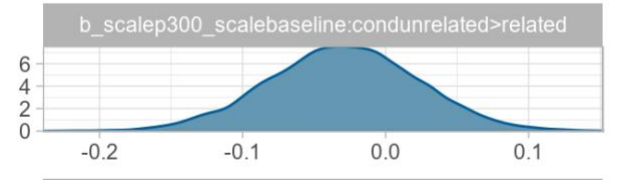
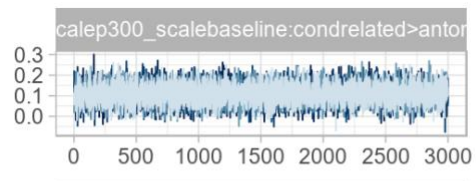
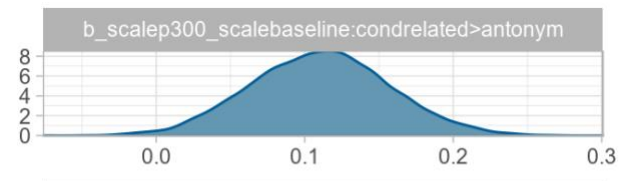
The correlations in the fixed-effects are small but significant (visible in the plots being somewhat elliptical, but with the major (long) axis being largely parallel to the x-axis) – this is line with component overlap.

	r	p
Intercept	0.33	< 0.001
related>antonym	0.17	< 0.001
unrelated>related	0.20	< 0.001

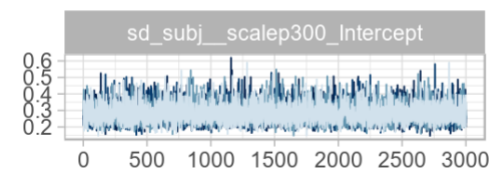
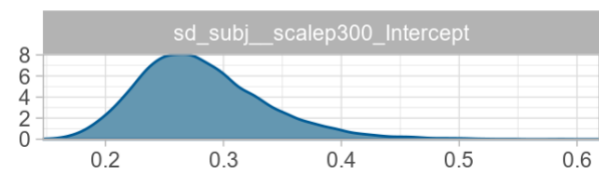
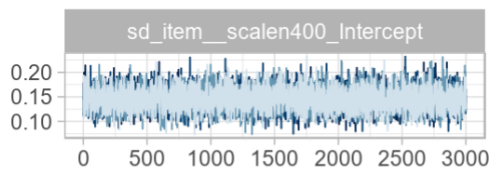
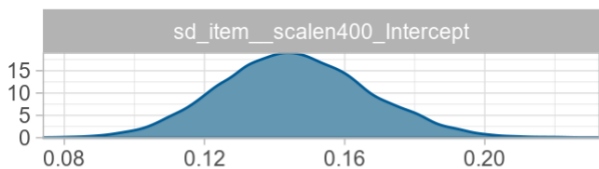
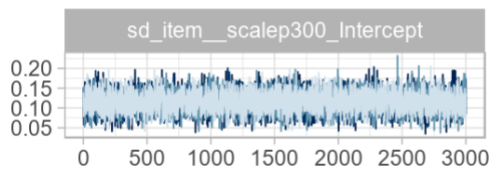
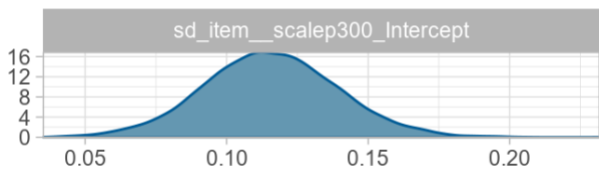
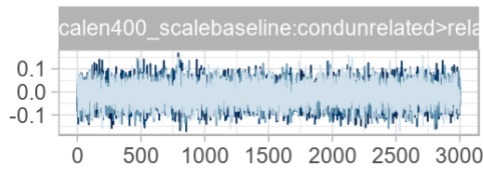
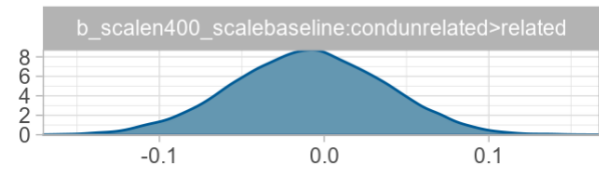
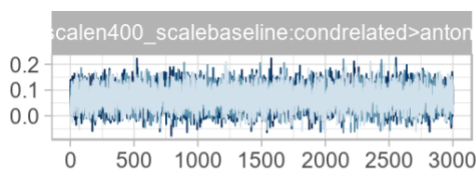
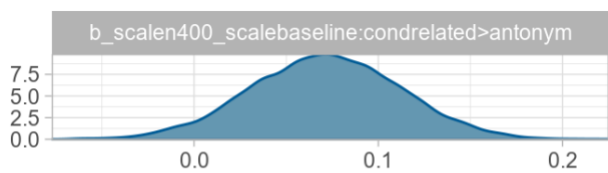


Markov Chains



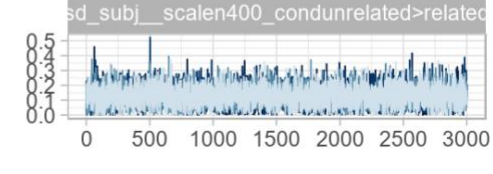
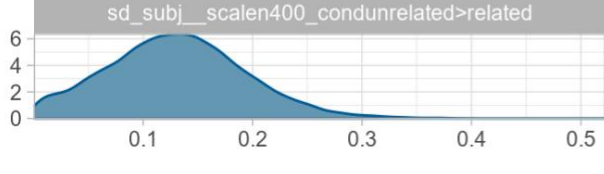
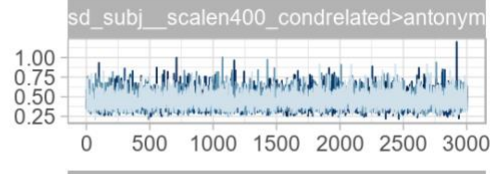
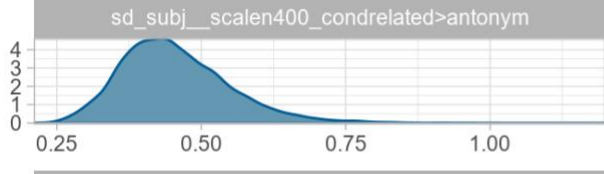
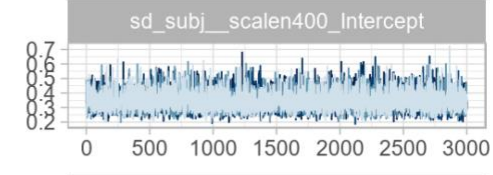
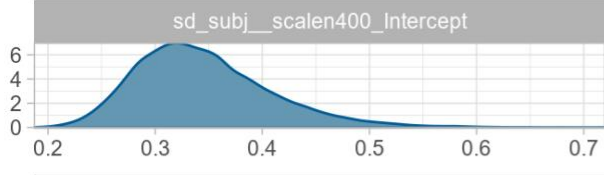
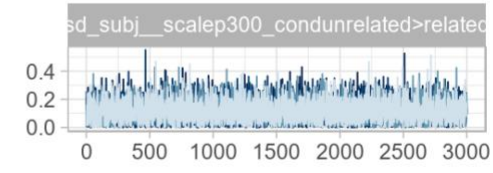
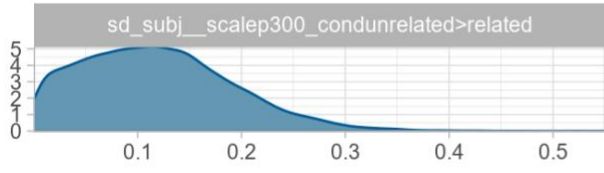
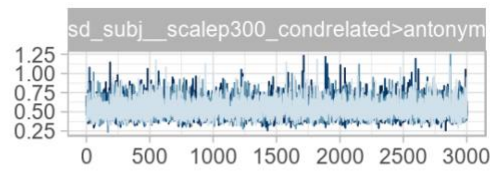
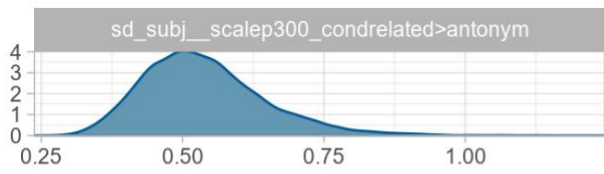


Chain
 — 1
 — 2
 — 3
 — 4



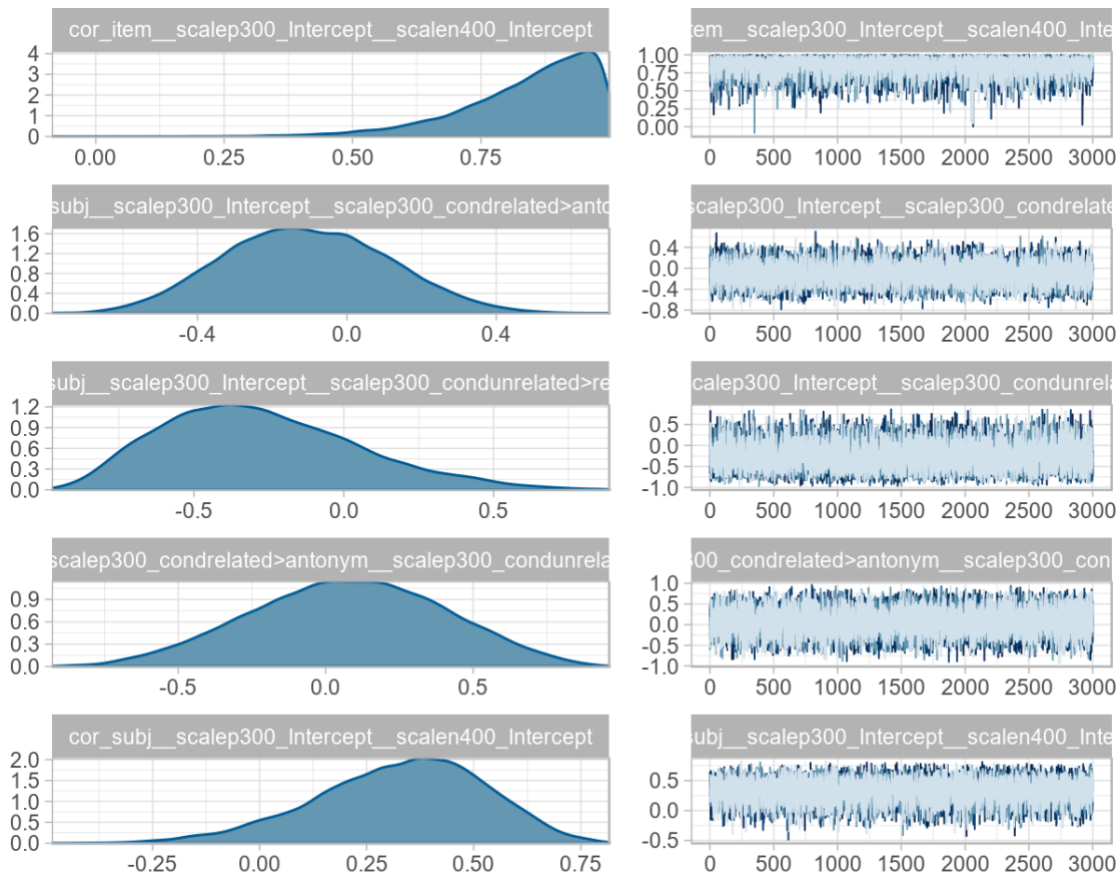
Chain

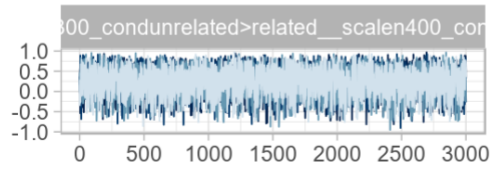
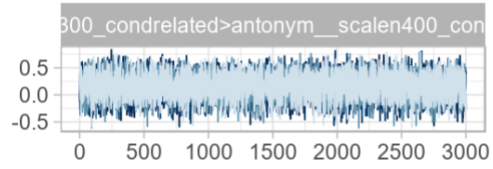
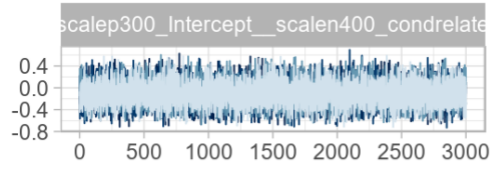
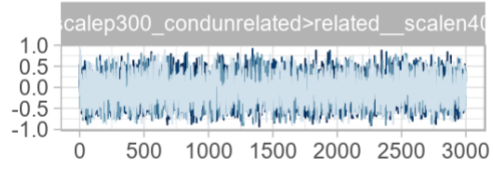
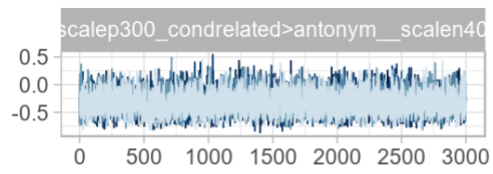
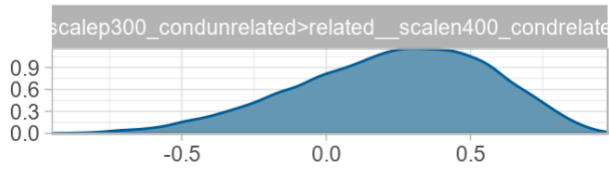
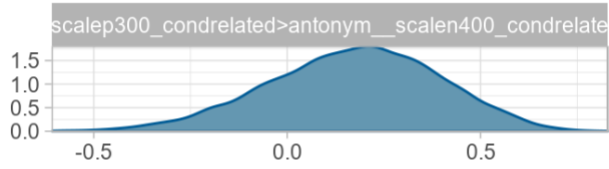
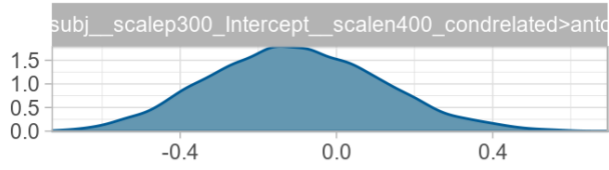
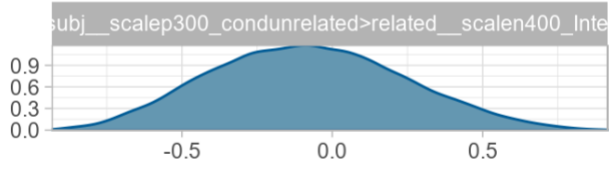
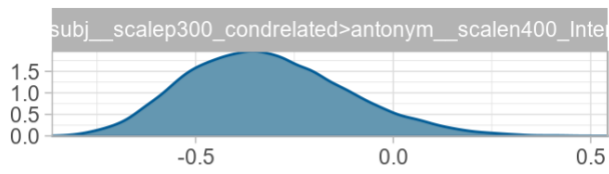
- 1
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Chain

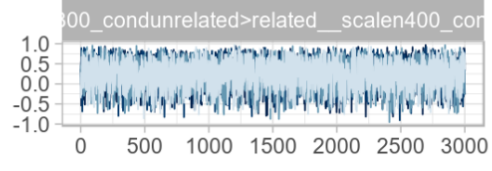
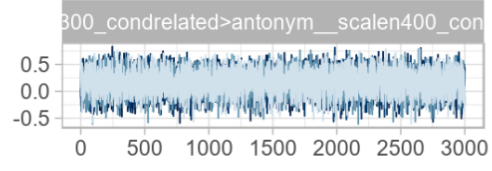
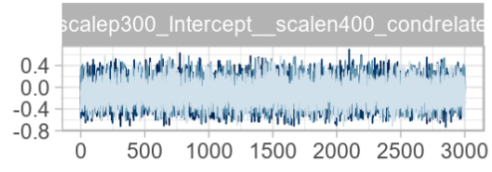
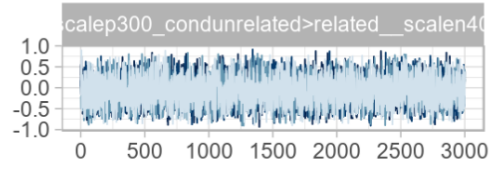
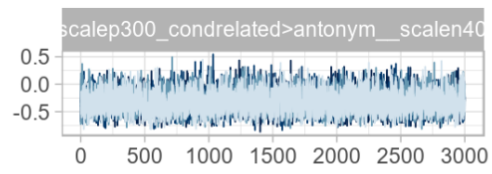
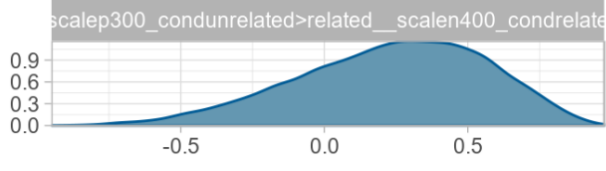
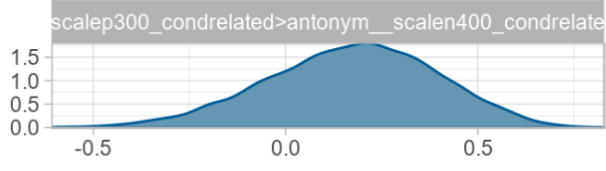
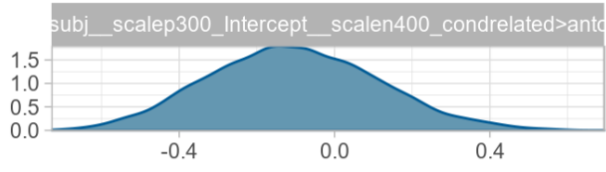
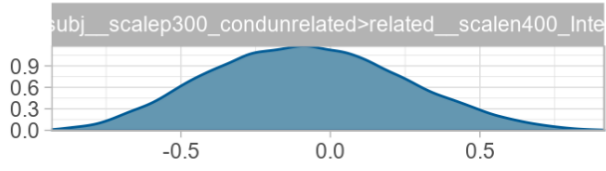
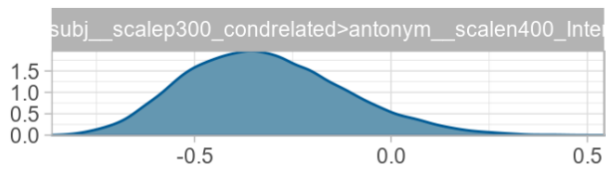
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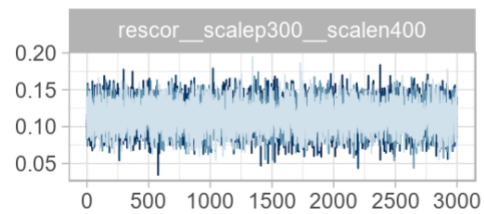
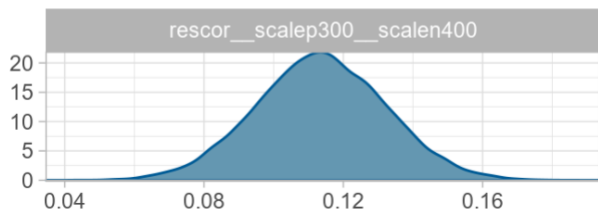
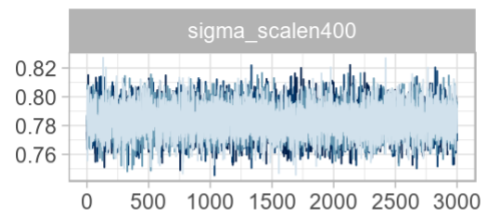
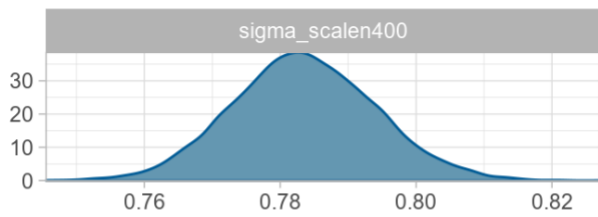
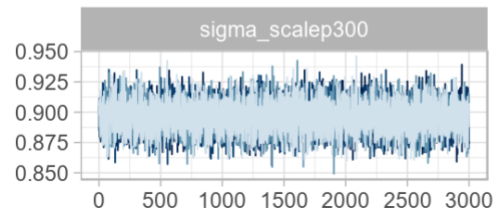
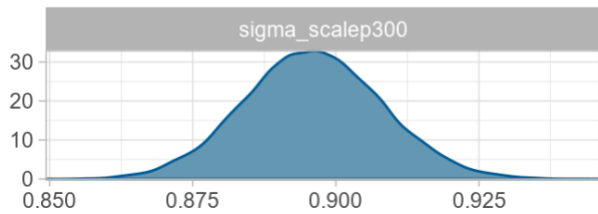
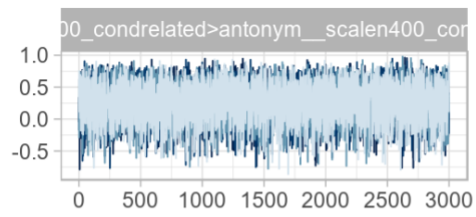
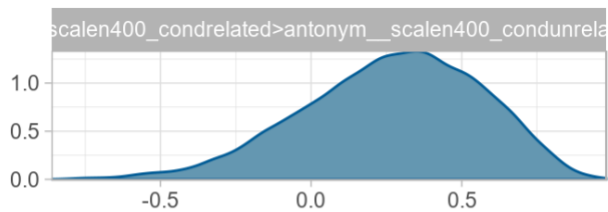
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Session Information

```
sessionInfo()
## R version 3.5.0 (2018-04-23)
## Platform: x86_64-suse-linux-gnu (64-bit)
## Running under: openSUSE Leap 15.0
##
## Matrix products: default
## BLAS: /usr/lib64/R/lib/libRblas.so
## LAPACK: /usr/lib64/R/lib/libRlapack.so
##
## locale:
## [1] LC_CTYPE=en_GB.UTF-8      LC_NUMERIC=C          LC_TIME=en_AU.UTF-8
LC_COLLATE=en_GB.UTF-8     LC_MONETARY=nl_NL.UTF-8
## [6] LC_MESSAGES=en_GB.UTF-8   LC_PAPER=nl_NL.UTF-8 LC_NAME=C             LC_ADDRESS=C
LC_TELEPHONE=C
## [11] LC_MEASUREMENT=nl_NL.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] stats      graphics  grDevices  utils      datasets  methods   base
##
## other attached packages:
## [1] psycho_0.4.91      neuropsychology_0.5.0 MASS_7.3-51.1      HDInterval_0.2.0
emmeans_1.3.2      magrittr_1.5        lmerOut_0.5
## [8] latex2exp_0.4.0    printr_0.1          car_3.0-2          carData_3.0-2
forcats_0.4.0      stringr_1.4.0       dplyr_0.8.1
## [15] purrr_0.3.2        readr_1.3.1         tidyr_0.8.3        tibble_2.1.1
ggplot2_3.1.1      tidyverse_1.2.1     remef_1.0.6.9000
## [22] brms_2.8.0         Rcpp_1.0.1          lme4_1.1-20        Matrix_1.2-15
##
## loaded via a namespace (and not attached):
## [1] estimability_1.3      wordcloud2_0.2.1    SparseM_1.77        ModelMetrics_1.2.2
lavaan_0.6-3          coda_0.19-2
## [7] nonnest2_0.5-2       acepack_1.4.1       knitr_1.23          dygraphs_1.1.1.6
data.table_1.12.0     rpart_4.1-13
## [13] inline_0.3.15       generics_0.0.2      callr_3.2.0         xml2_1.2.0
lubridate_1.7.4       httpuv_1.5.1
## [19] StanHeaders_2.18.1   assertthat_0.2.1    d3Network_0.5.2.1   gower_0.1.2
xfun_0.7              hms_0.4.2
## [25] bayesplot_1.6.0     evaluate_0.14       promises_1.0.1      fansi_0.4.0
readxl_1.2.0          igraph_1.2.4.1
## [31] htmlwidgets_1.3     mcmc_0.9-5          stats4_3.5.0        crosstalk_1.0.0
backports_1.1.4       pbivnorm_0.6.0
## [37] markdown_0.9        ggcorrplot_0.1.2    MCMCpack_1.4-4      vctrs_0.1.0
quantreg_5.38         abind_1.4-5
## [43] caret_6.0-81        withr_2.1.2         checkmate_1.9.1     fdrtool_1.2.15
xts_0.11-2            prettyunits_1.0.2
## [49] mnormt_1.5-5        cluster_2.0.7-1     lazyeval_0.2.2      crayon_1.3.4
recipes_0.1.4         pkgconfig_2.0.2
## [55] slam_0.1-44         labeling_0.3         nlme_3.1-137        ggpm_2.3
nnet_7.3-12           rlang_0.3.4
## [61] miniUI_0.1.1.1      colourpicker_1.0    MatrixModels_0.4-1  sandwich_2.5-1
modelr_0.1.2          cellranger_1.1.0
## [67] tcltk_3.5.0         matrixStats_0.54.0  loo_2.1.0           boot_1.3-20
zoo_1.8-5             base64enc_0.1-3
## [73] whisker_0.3-2       ggribbles_0.5.1     processx_3.3.0      rjson_0.2.20
png_0.1-7            jpeg_0.1-8
## [79] shinystan_2.5.0     scales_1.0.0        plyr_1.8.4          threejs_0.3.1
compiler_3.5.0        rstantools_1.5.1
## [85] RColorBrewer_1.1-2 cli_1.1.0           lmerTest_3.1-0      pbapply_1.4-0
ps_1.3.0              Brodbringnag_1.2-6
## [91] htmlTable_1.13.1    Formula_1.2-3       tidyselect_0.2.5    stringi_1.4.3
highr_0.8             yaml_2.2.0
## [97] latticeExtra_0.6-28 bridgesampling_0.6-0 grid_3.5.0          manipulate_1.0.1
tools_3.5.0           parallel_3.5.0
## [103] rio_0.5.16          rstudioapi_0.10     foreach_1.4.4       foreign_0.8-71
gridExtra_2.3         prodlim_2018.04.18
## [109] BDgraph_2.59        digest_0.6.18       shiny_1.3.2         lava_1.6.4
ppcor_1.1            broom_0.5.2
## [115] BayesFactor_0.9.12-4.2 later_0.8.0          httr_1.4.0          rsconnect_0.8.13
psych_1.8.12         colorspace_1.4-1
```



```

## [121] blavaan_0.3-4          rvest_0.3.2          splines_3.5.0        expm_0.999-3
shinythemes_1.1.2        rstanarm_2.18.2      xtable_1.8-4        jsonlite_1.6         nloptr_1.2.1
## [127] MuMIn_1.42.1             xtable_1.8-4        jsonlite_1.6         nloptr_1.2.1
corpcor_1.6.9           timeDate_3043.102   zeallot_0.1.0       NLP_0.2-0
## [133] rstan_2.18.2            glasso_1.10         zeallot_0.1.0       NLP_0.2-0
ipred_0.9-8             nFactors_2.3.3      Hmisc_4.2-0         pillar_1.4.0
## [139] R6_2.4.0                tm_0.7-6           Hmisc_4.2-0         pillar_1.4.0
htmltools_0.3.6        mime_0.6             DT_0.5              class_7.3-15
## [145] glue_1.3.1              minqa_1.2.4        DT_0.5              class_7.3-15
codetools_0.2-16       pkgbuild_1.0.3      lattice_0.20-38     numDeriv_2016.8-1
## [151] mvtnorm_1.0-10         utf8_1.1.4         lattice_0.20-38     numDeriv_2016.8-1
huge_1.3.2             curl_3.3            zip_1.0.0           shinyjs_1.0
## [157] DescTools_0.99.28      gtools_3.8.1       zip_1.0.0           shinyjs_1.0
openxlsx_4.1.0         survival_2.43-3     qgraph_1.6.3       munsell_0.5.0
## [163] CompQuadForm_1.4.3     rmarkdown_1.12     qgraph_1.6.3       munsell_0.5.0
iterators_1.0.10      haven_2.0.0         gtable_0.3.0
## [169] reshape2_1.4.3        gtable_0.3.0

```