# STATS 271 Final Project

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```
library(mlmRev)
library(tidyverse)
library(rstan)
library(rstanarm)
library(gridExtra)
library(loo)
library(brms)
library(ggplot2)
theme_set(theme_minimal())
data(Contraception)
cont <- Contraception
#save.image("~/Desktop/271_project.RData")
load("~/Desktop/271_project.RData")
```

## 1. EDA and summary statistics

```
use_cont <- filter(cont, use==1)
group_cont_use <- cont %>% group_by(district) %>% summarise(use=mean(use))
group_region_use <- cont %>% group_by(urban) %>% summarise(use=mean(use))
table(cont$livch)
group_livch_use <- cont %>% group_by(livch) %>% summarise(use=mean(use))
mean(cont$use)
cont2 <- cont
cont2$age <- cont2$age + 30
test <- filter(cont2, age > 50 & age <= 55)
mean(test$use)

district_mean_hist <- group_cont_use %>% ggplot(aes(x=use)) +
  geom_histogram(binwidth=0.05, color="black", fill="white") +
  theme_bw() + ggtitle("Distribution of percentage of contraception use by district") +
  xlab("Percentage of contraception use") + theme(panel.grid.major = element_blank(),
                                                  panel.grid.minor = element_blank(),
panel.background = element_blank(), axis.line = element_line(colour = "black"))

cont_2 <- use_cont %>% ggplot(aes(x = factor(urban), fill = factor(livch))) +
  geom_bar(position="dodge") + theme_bw() +
  ggtitle("Use of contraception by urban/rural residence and number of living children") +
  xlab("Urban Residence") + theme(panel.grid.major = element_blank(), panel.grid.minor = element_blank()
panel.background = element_blank(), axis.line = element_line(colour = "black")) +
  scale_fill_discrete(name="Number of living children")
```

```
grid.arrange(district_mean_hist, cont_2, ncol=2)
```

# 2. Modeling and posterior checking

## Model 1. Varying intercept model with no predictor

```
varying_inter_nopred_mod <- stan_glmer(formula = use ~ 1 + (1|district),
                         data = cont,
                         seed = 271,
                         cores = getOption("mc.cores", 4L),
                         family = binomial(link = "logit"))
```

```
summary(varying_inter_nopred_mod,  digits = 3)
```

```
##
## Model Info:
##  function:     stan_glmer
##  family:       binomial [logit]
##  formula:      use ~ 1 + (1 | district)
##  algorithm:    sampling
##  sample:       4000 (posterior sample size)
##  priors:       see help('prior_summary')
##  observations: 1934
##  groups:       district (60)
##
## Estimates:
##                                          mean   sd     10%    50%    90%
## (Intercept)                             -0.540  0.089 -0.653 -0.537 -0.427
## b[(Intercept) district:1]               -0.456  0.208 -0.725 -0.452 -0.194
## b[(Intercept) district:2]               -0.046  0.333 -0.480 -0.045  0.382
## b[(Intercept) district:3]                0.302  0.499 -0.319  0.288  0.951
## b[(Intercept) district:4]                0.347  0.308 -0.046  0.345  0.743
## b[(Intercept) district:5]               -0.034  0.284 -0.406 -0.030  0.328
## b[(Intercept) district:6]               -0.279  0.254 -0.609 -0.273  0.044
## b[(Intercept) district:7]               -0.218  0.366 -0.683 -0.214  0.236
## b[(Intercept) district:8]                0.021  0.293 -0.354  0.022  0.398
## b[(Intercept) district:9]               -0.168  0.351 -0.626 -0.157  0.272
## b[(Intercept) district:10]              -0.603  0.424 -1.159 -0.587 -0.076
## b[(Intercept) district:11]              -1.005  0.427 -1.566 -0.977 -0.482
## b[(Intercept) district:12]              -0.070  0.311 -0.473 -0.064  0.325
## b[(Intercept) district:13]               0.118  0.328 -0.301  0.114  0.530
## b[(Intercept) district:14]               0.933  0.201  0.677  0.935  1.194
## b[(Intercept) district:15]              -0.020  0.337 -0.449 -0.021  0.405
## b[(Intercept) district:16]               0.405  0.354 -0.043  0.401  0.847
## b[(Intercept) district:17]              -0.209  0.346 -0.655 -0.203  0.226
## b[(Intercept) district:18]              -0.091  0.275 -0.442 -0.089  0.254
## b[(Intercept) district:19]               0.038  0.327 -0.375  0.038  0.458
## b[(Intercept) district:20]               0.058  0.371 -0.421  0.062  0.534
## b[(Intercept) district:21]               0.045  0.354 -0.408  0.050  0.494
## b[(Intercept) district:22]              -0.428  0.360 -0.905 -0.419  0.026
## b[(Intercept) district:23]              -0.222  0.389 -0.722 -0.216  0.266
```

```
## b[(Intercept) district:24]              -0.635  0.409 -1.163 -0.625 -0.128
## b[(Intercept) district:25]               0.269  0.237 -0.040  0.270  0.566
## b[(Intercept) district:26]               0.025  0.388 -0.466  0.029  0.519
## b[(Intercept) district:27]              -0.643  0.312 -1.054 -0.626 -0.253
## b[(Intercept) district:28]              -0.424  0.275 -0.774 -0.420 -0.077
## b[(Intercept) district:29]              -0.264  0.314 -0.661 -0.256  0.134
## b[(Intercept) district:30]               0.401  0.245  0.090  0.397  0.716
## b[(Intercept) district:31]               0.241  0.301 -0.144  0.234  0.623
## b[(Intercept) district:32]              -0.433  0.350 -0.886 -0.425  0.004
## b[(Intercept) district:33]               0.122  0.380 -0.367  0.119  0.606
## b[(Intercept) district:34]               0.813  0.306  0.429  0.803  1.212
## b[(Intercept) district:35]               0.410  0.257  0.079  0.404  0.746
## b[(Intercept) district:36]              -0.043  0.369 -0.514 -0.042  0.414
## b[(Intercept) district:37]               0.316  0.382 -0.183  0.313  0.808
## b[(Intercept) district:38]              -0.168  0.393 -0.681 -0.169  0.328
## b[(Intercept) district:39]               0.338  0.313 -0.062  0.336  0.729
## b[(Intercept) district:40]               0.279  0.274 -0.063  0.278  0.637
## b[(Intercept) district:41]               0.333  0.323 -0.083  0.332  0.747
## b[(Intercept) district:42]               0.306  0.399 -0.202  0.300  0.805
## b[(Intercept) district:43]               0.502  0.282  0.147  0.497  0.867
## b[(Intercept) district:44]              -0.410  0.346 -0.852 -0.412  0.021
## b[(Intercept) district:45]              -0.112  0.282 -0.475 -0.110  0.249
## b[(Intercept) district:46]               0.534  0.213  0.265  0.533  0.806
## b[(Intercept) district:47]               0.202  0.383 -0.280  0.199  0.698
## b[(Intercept) district:48]               0.465  0.266  0.137  0.461  0.811
## b[(Intercept) district:49]              -0.333  0.478 -0.946 -0.319  0.256
## b[(Intercept) district:50]               0.236  0.360 -0.217  0.234  0.698
## b[(Intercept) district:51]               0.265  0.295 -0.111  0.266  0.646
## b[(Intercept) district:52]               0.242  0.240 -0.067  0.239  0.557
## b[(Intercept) district:53]               0.112  0.343 -0.337  0.116  0.551
## b[(Intercept) district:55]              -0.237  0.450 -0.814 -0.231  0.323
## b[(Intercept) district:56]               0.637  0.278  0.276  0.635  0.991
## b[(Intercept) district:57]              -0.524  0.353 -0.978 -0.512 -0.089
## b[(Intercept) district:58]               0.231  0.298 -0.153  0.236  0.604
## b[(Intercept) district:59]              -0.467  0.423 -1.012 -0.460  0.060
## b[(Intercept) district:60]              -0.459  0.338 -0.893 -0.446 -0.035
## b[(Intercept) district:61]              -0.511  0.300 -0.900 -0.499 -0.140
## Sigma[district:(Intercept),(Intercept)]  0.274  0.089  0.172  0.262  0.393
##
## Fit Diagnostics:
##            mean   sd    10%   50%   90%
## mean_PPD 0.393  0.015 0.373 0.393 0.412
##
## The mean_ppd is the sample average posterior predictive distribution of the outcome variable (for de
##
## MCMC diagnostics
##                                        mcse  Rhat  n_eff
## (Intercept)                            0.002 1.002 1616
## b[(Intercept) district:1]              0.003 1.000 4142
## b[(Intercept) district:2]              0.005 0.999 5197
## b[(Intercept) district:3]              0.007 0.999 5508
## b[(Intercept) district:4]              0.004 0.999 6021
## b[(Intercept) district:5]              0.004 1.000 5397
## b[(Intercept) district:6]              0.004 1.000 4613
```

```
## b[(Intercept) district:7]              0.005 1.000 5412
## b[(Intercept) district:8]              0.004 1.000 5477
## b[(Intercept) district:9]              0.004 0.999 6521
## b[(Intercept) district:10]             0.006 1.000 4502
## b[(Intercept) district:11]             0.007 1.000 4254
## b[(Intercept) district:12]             0.004 1.000 6266
## b[(Intercept) district:13]             0.004 1.001 5372
## b[(Intercept) district:14]             0.003 1.000 3834
## b[(Intercept) district:15]             0.004 1.000 6235
## b[(Intercept) district:16]             0.005 1.000 4926
## b[(Intercept) district:17]             0.004 0.999 6865
## b[(Intercept) district:18]             0.004 1.000 4971
## b[(Intercept) district:19]             0.004 1.000 5295
## b[(Intercept) district:20]             0.005 0.999 5163
## b[(Intercept) district:21]             0.005 1.000 6193
## b[(Intercept) district:22]             0.005 0.999 6035
## b[(Intercept) district:23]             0.005 1.000 7110
## b[(Intercept) district:24]             0.006 0.999 4429
## b[(Intercept) district:25]             0.003 1.000 5123
## b[(Intercept) district:26]             0.005 1.000 6568
## b[(Intercept) district:27]             0.005 1.000 4761
## b[(Intercept) district:28]             0.004 0.999 5379
## b[(Intercept) district:29]             0.004 1.000 5286
## b[(Intercept) district:30]             0.004 1.000 4600
## b[(Intercept) district:31]             0.004 1.000 4815
## b[(Intercept) district:32]             0.004 1.000 6394
## b[(Intercept) district:33]             0.005 1.000 6574
## b[(Intercept) district:34]             0.004 0.999 5017
## b[(Intercept) district:35]             0.004 1.000 4694
## b[(Intercept) district:36]             0.005 0.999 5971
## b[(Intercept) district:37]             0.005 1.000 6009
## b[(Intercept) district:38]             0.005 1.000 5663
## b[(Intercept) district:39]             0.004 1.001 4835
## b[(Intercept) district:40]             0.004 1.000 4482
## b[(Intercept) district:41]             0.005 1.000 5091
## b[(Intercept) district:42]             0.005 1.000 6060
## b[(Intercept) district:43]             0.004 1.000 4553
## b[(Intercept) district:44]             0.005 1.000 5537
## b[(Intercept) district:45]             0.004 0.999 5705
## b[(Intercept) district:46]             0.003 1.000 3921
## b[(Intercept) district:47]             0.005 1.000 5410
## b[(Intercept) district:48]             0.004 0.999 4548
## b[(Intercept) district:49]             0.006 1.000 5843
## b[(Intercept) district:50]             0.005 1.001 5061
## b[(Intercept) district:51]             0.004 1.000 4903
## b[(Intercept) district:52]             0.004 1.000 4649
## b[(Intercept) district:53]             0.004 0.999 6174
## b[(Intercept) district:55]             0.006 0.999 5630
## b[(Intercept) district:56]             0.004 1.000 4354
## b[(Intercept) district:57]             0.005 1.000 4694
## b[(Intercept) district:58]             0.004 1.000 4809
## b[(Intercept) district:59]             0.005 0.999 6144
## b[(Intercept) district:60]             0.005 0.999 5588
## b[(Intercept) district:61]             0.004 1.000 4664
```

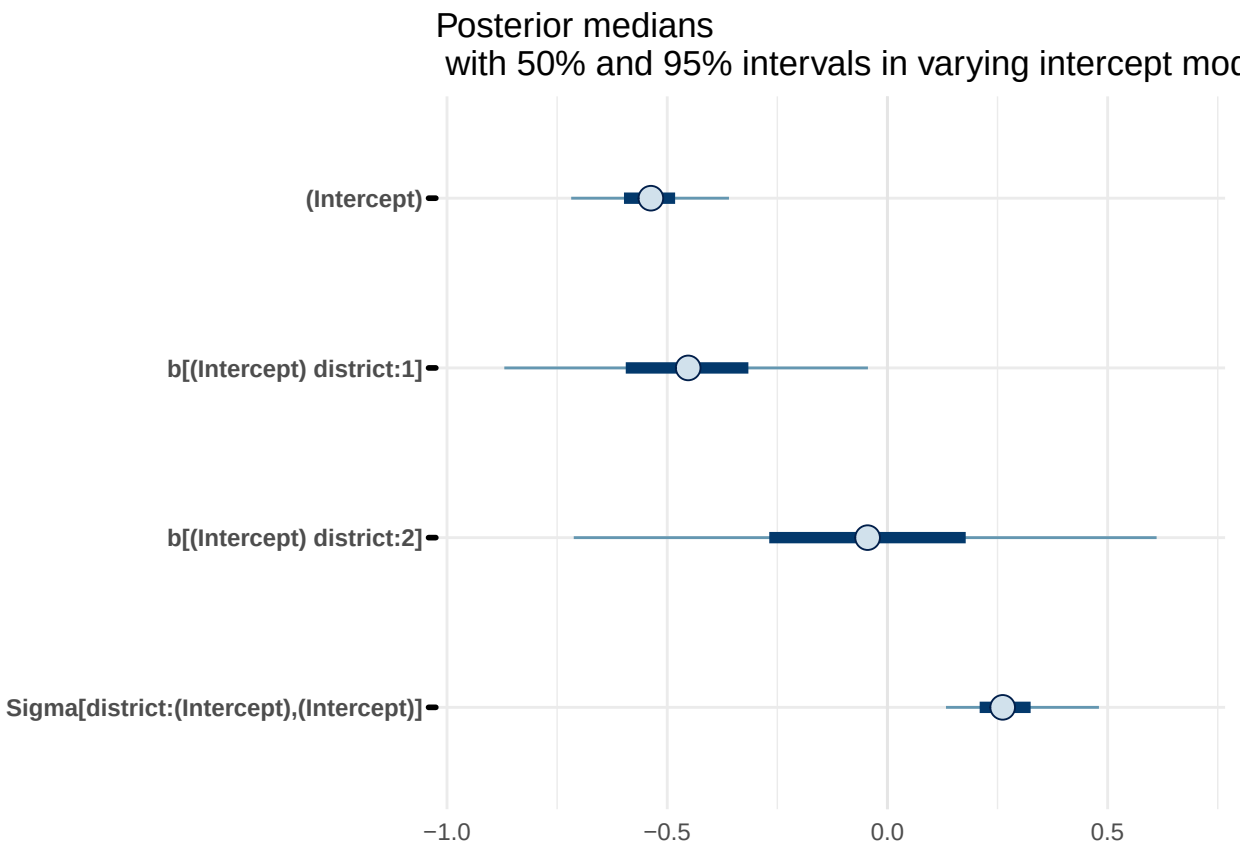
```
## Sigma[district:(Intercept),(Intercept)] 0.002 1.000 1396
## mean_PPD                                0.000 1.000 4276
## log-posterior                           0.270 1.001  818
##
## For each parameter, mcse is Monte Carlo standard error, n_eff is a crude measure of effective sample
```

```
prior_summary(varying_inter_nopred_mod)
```

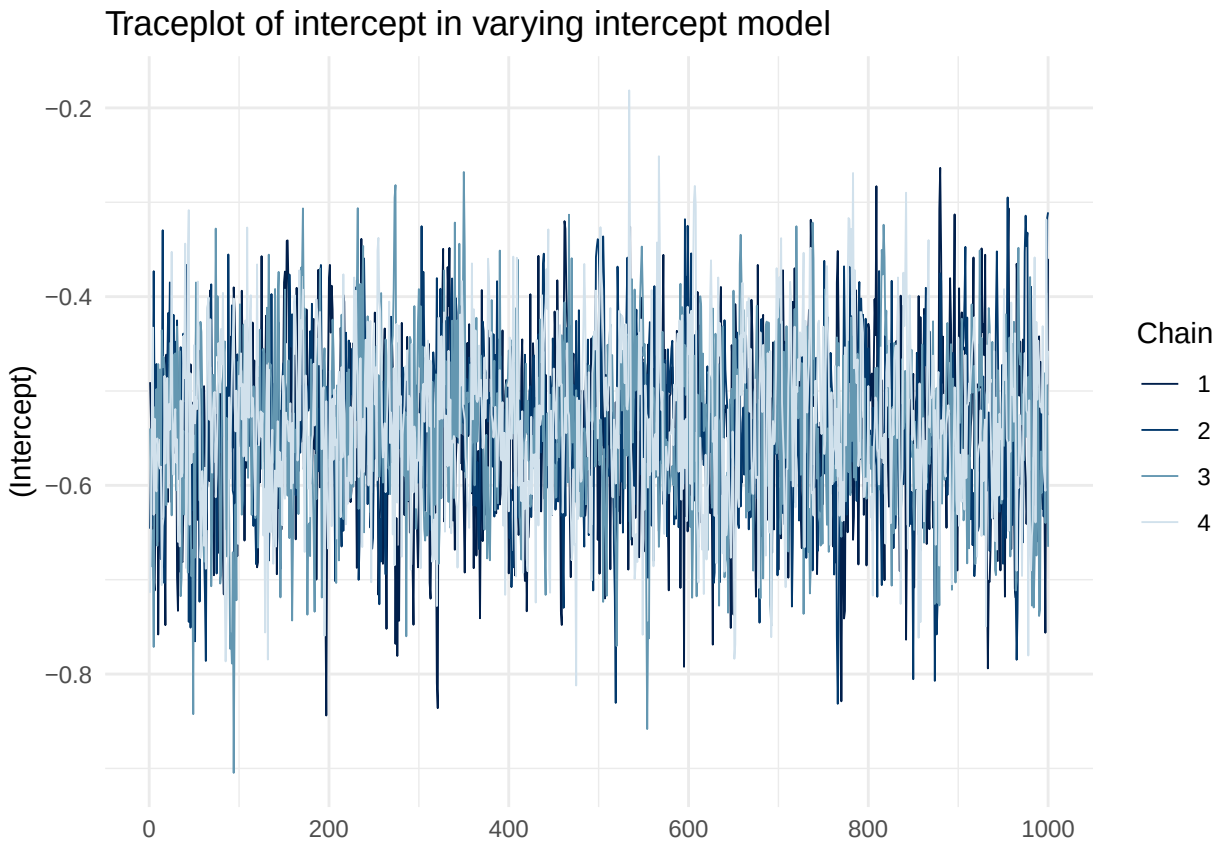
```
## Priors for model 'varying_inter_nopred_mod'
## ------
## Intercept (after predictors centered)
##  ~ normal(location = 0, scale = 10)
##
## Covariance
##  ~ decov(reg. = 1, conc. = 1, shape = 1, scale = 1)
## ------
## See help('prior_summary.stanreg') for more details
```

```
summary(varying_inter_nopred_mod,  digits = 3,
        pars=c("(Intercept)", "b[(Intercept) district:1]",
               "b[(Intercept) district:2]", "Sigma[district:(Intercept),(Intercept)]"),
        probs = c(0.025, 0.5, 0.975))
```

```
plot(varying_inter_nopred_mod, pars=c("(Intercept)",
                                      "b[(Intercept) district:1]", "b[(Intercept) district:2]",
                                      "Sigma[district:(Intercept),(Intercept)]"),
     prob = 0.5, prob_outer = 0.95) + ggplot2::ggtitle("Posterior medians \n with 50% and 95% intervals
```

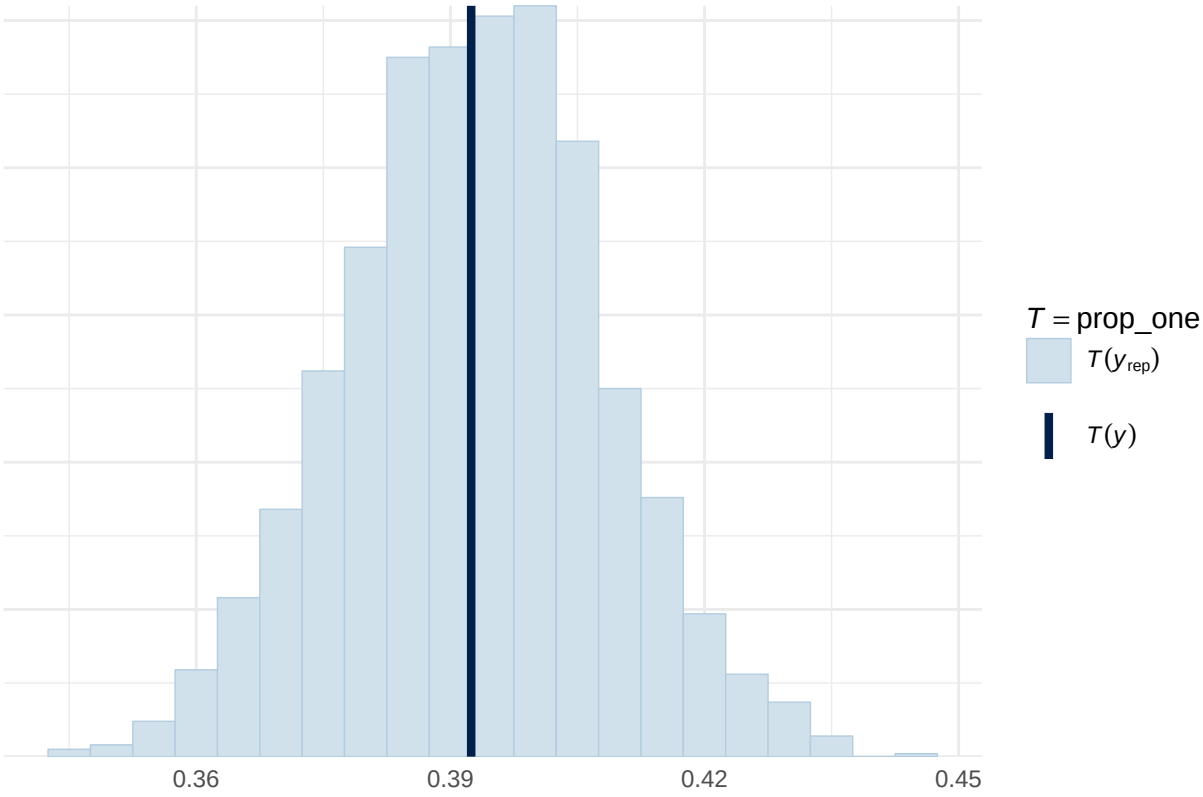


```
plot(varying_inter_nopred_mod, "trace", pars = "(Intercept)") +
  ggplot2::ggtitle("Traceplot of intercept in varying intercept model")
```




Posterior checking

```
prop_one <- function(y) mean(y == 1)
prop_zero_test1 <- pp_check(varying_inter_nopred_mod, plotfun = "stat",
                            stat = "prop_one", binwidth=0.005)
prop_zero_test1 + ggtitle("Posterior checking of varying intercept model with no predictors")
```




### Model 2. Varying intercept model with predictors

all the predictors have the same slope, but allows intercept to vary among districts.

```
varying_intercept_mod <- stan_glmer(formula = use ~ 1 + urban + age + livch + (1|district),
                         data = cont,
                         seed = 271,
                         cores = getOption("mc.cores", 4L),
                         family = binomial(link = "logit"))
```

```
prior_summary(varying_intercept_mod)
```

```
## Priors for model 'varying_intercept_mod'
## ------
## Intercept (after predictors centered)
##  ~ normal(location = 0, scale = 10)
##
## Coefficients
##   Specified prior:
##     ~ normal(location = [0,0,0,...], scale = [2.5,2.5,2.5,...])
##   Adjusted prior:
##     ~ normal(location = [0,0,0,...], scale = [2.50,0.28,2.50,...])
##
## Covariance
##  ~ decov(reg. = 1, conc. = 1, shape = 1, scale = 1)
## ------
## See help('prior_summary.stanreg') for more details
```

```r
summary(varying_intercept_mod, digits = 3)
```

```
##
## Model Info:
##  function:     stan_glmer
##  family:       binomial [logit]
##  formula:      use ~ 1 + urban + age + livch + (1 | district)
##  algorithm:    sampling
##  sample:       4000 (posterior sample size)
##  priors:       see help('prior_summary')
##  observations: 1934
##  groups:       district (60)
##
## Estimates:
##                                          mean   sd     10%    50%    90%
## (Intercept)                             -1.686  0.145 -1.875 -1.683 -1.504
## urbanY                                   0.729  0.122  0.571  0.730  0.884
## age                                     -0.026  0.008 -0.036 -0.027 -0.016
## livch1                                   1.103  0.153  0.906  1.098  1.303
## livch2                                   1.372  0.172  1.154  1.371  1.591
## livch3+                                  1.338  0.176  1.118  1.338  1.563
## b[(Intercept) district:1]               -0.729  0.214 -1.007 -0.730 -0.462
## b[(Intercept) district:2]               -0.041  0.347 -0.475 -0.042  0.393
## b[(Intercept) district:3]                0.226  0.455 -0.350  0.217  0.808
## b[(Intercept) district:4]                0.194  0.309 -0.201  0.195  0.594
## b[(Intercept) district:5]                0.049  0.290 -0.330  0.051  0.418
## b[(Intercept) district:6]               -0.230  0.252 -0.563 -0.224  0.091
## b[(Intercept) district:7]               -0.148  0.363 -0.611 -0.142  0.309
## b[(Intercept) district:8]                0.104  0.285 -0.270  0.109  0.464
## b[(Intercept) district:9]               -0.235  0.324 -0.650 -0.232  0.179
## b[(Intercept) district:10]              -0.403  0.398 -0.916 -0.386  0.093
## b[(Intercept) district:11]              -0.763  0.417 -1.299 -0.739 -0.256
## b[(Intercept) district:12]              -0.089  0.302 -0.468 -0.088  0.294
## b[(Intercept) district:13]               0.125  0.330 -0.288  0.127  0.539
## b[(Intercept) district:14]               0.612  0.218  0.330  0.615  0.888
## b[(Intercept) district:15]              -0.057  0.338 -0.488 -0.047  0.370
## b[(Intercept) district:16]               0.563  0.346  0.128  0.556  1.002
## b[(Intercept) district:17]              -0.143  0.332 -0.567 -0.138  0.279
## b[(Intercept) district:18]              -0.081  0.270 -0.430 -0.081  0.257
## b[(Intercept) district:19]               0.113  0.317 -0.293  0.112  0.528
## b[(Intercept) district:20]               0.200  0.361 -0.261  0.199  0.658
## b[(Intercept) district:21]               0.004  0.349 -0.437  0.007  0.437
## b[(Intercept) district:22]              -0.389  0.349 -0.841 -0.383  0.051
## b[(Intercept) district:23]              -0.176  0.362 -0.649 -0.169  0.282
## b[(Intercept) district:24]              -0.492  0.407 -1.022 -0.472  0.004
## b[(Intercept) district:25]               0.200  0.235 -0.100  0.201  0.506
## b[(Intercept) district:26]               0.020  0.384 -0.468  0.015  0.502
## b[(Intercept) district:27]              -0.487  0.300 -0.876 -0.479 -0.107
## b[(Intercept) district:28]              -0.360  0.276 -0.706 -0.358 -0.016
## b[(Intercept) district:29]              -0.126  0.317 -0.535 -0.120  0.277
## b[(Intercept) district:30]               0.436  0.247  0.122  0.438  0.751
## b[(Intercept) district:31]               0.287  0.295 -0.089  0.284  0.663
## b[(Intercept) district:32]              -0.411  0.334 -0.834 -0.398  0.009
## b[(Intercept) district:33]              -0.083  0.362 -0.539 -0.081  0.385
```

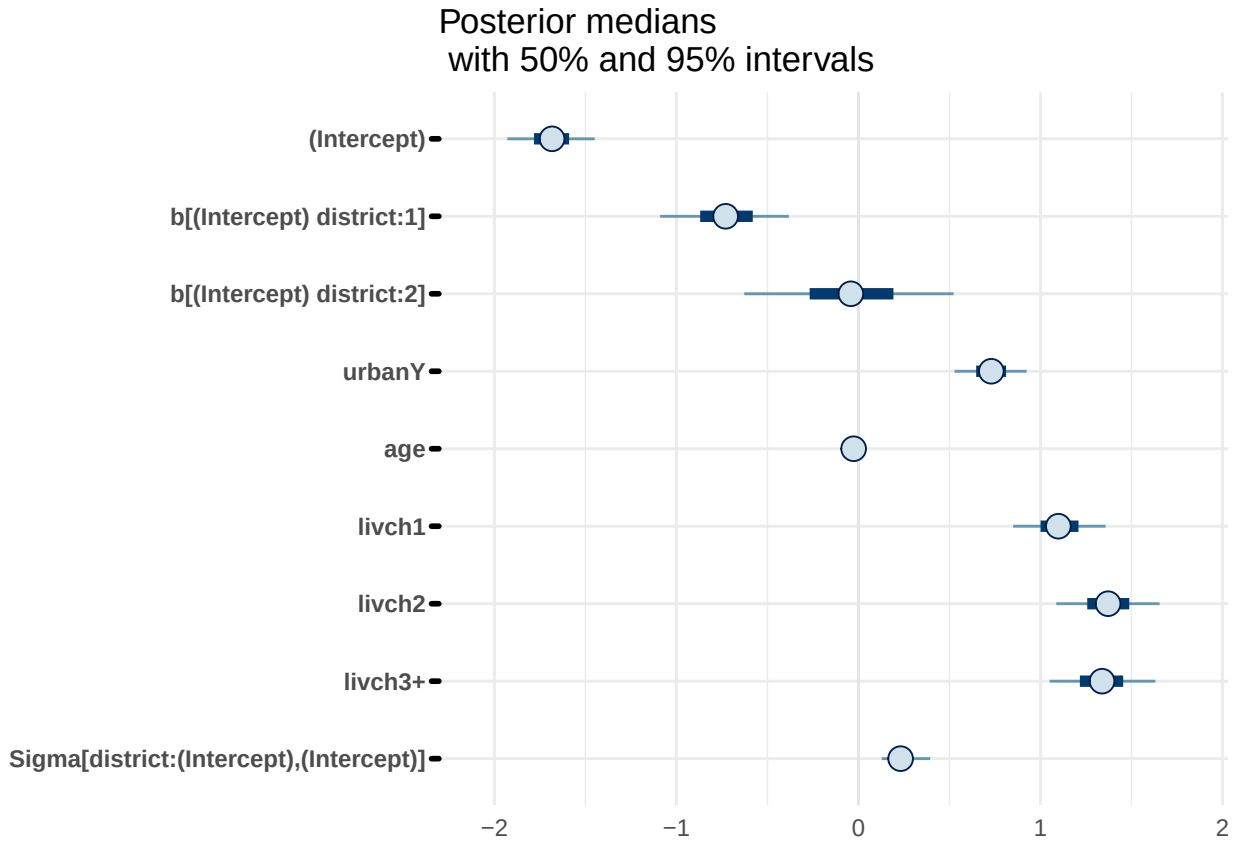
```
## b[(Intercept) district:34]                0.740  0.307  0.349  0.725  1.155
## b[(Intercept) district:35]                0.232  0.267 -0.103  0.231  0.581
## b[(Intercept) district:36]               -0.097  0.363 -0.555 -0.097  0.357
## b[(Intercept) district:37]                0.337  0.371 -0.147  0.334  0.817
## b[(Intercept) district:38]               -0.203  0.382 -0.703 -0.191  0.278
## b[(Intercept) district:39]                0.469  0.326  0.062  0.467  0.893
## b[(Intercept) district:40]                0.138  0.276 -0.216  0.132  0.491
## b[(Intercept) district:41]                0.319  0.325 -0.088  0.311  0.743
## b[(Intercept) district:42]                0.222  0.385 -0.265  0.216  0.723
## b[(Intercept) district:43]                0.495  0.276  0.139  0.491  0.852
## b[(Intercept) district:44]               -0.292  0.338 -0.732 -0.288  0.131
## b[(Intercept) district:45]               -0.165  0.288 -0.539 -0.153  0.200
## b[(Intercept) district:46]                0.573  0.216  0.293  0.575  0.848
## b[(Intercept) district:47]                0.207  0.368 -0.255  0.206  0.669
## b[(Intercept) district:48]                0.440  0.283  0.075  0.438  0.795
## b[(Intercept) district:49]               -0.211  0.474 -0.819 -0.198  0.378
## b[(Intercept) district:50]                0.303  0.351 -0.141  0.300  0.758
## b[(Intercept) district:51]                0.053  0.280 -0.311  0.048  0.418
## b[(Intercept) district:52]                0.198  0.246 -0.118  0.196  0.516
## b[(Intercept) district:53]               -0.121  0.362 -0.584 -0.122  0.334
## b[(Intercept) district:55]               -0.341  0.419 -0.882 -0.334  0.196
## b[(Intercept) district:56]                0.595  0.283  0.236  0.594  0.962
## b[(Intercept) district:57]               -0.449  0.345 -0.888 -0.440 -0.010
## b[(Intercept) district:58]                0.231  0.297 -0.148  0.232  0.610
## b[(Intercept) district:59]               -0.439  0.414 -0.955 -0.430  0.075
## b[(Intercept) district:60]               -0.413  0.314 -0.824 -0.402 -0.032
## b[(Intercept) district:61]               -0.555  0.295 -0.938 -0.547 -0.181
## Sigma[district:(Intercept),(Intercept)]  0.242  0.083  0.149  0.232  0.346
##
## Fit Diagnostics:
##            mean   sd    10%   50%   90%
## mean_PPD 0.393  0.015 0.374 0.392 0.412
##
## The mean_ppd is the sample average posterior predictive distribution of the outcome variable (for de
##
## MCMC diagnostics
##                                       mcse  Rhat  n_eff
## (Intercept)                           0.003 0.999 2143
## urbanY                                0.002 1.000 4842
## age                                   0.000 1.000 3272
## livch1                                0.003 1.000 3584
## livch2                                0.003 1.000 2965
## livch3+                               0.004 0.999 2305
## b[(Intercept) district:1]             0.003 1.000 4266
## b[(Intercept) district:2]             0.004 1.000 5978
## b[(Intercept) district:3]             0.006 1.000 6378
## b[(Intercept) district:4]             0.004 1.000 6126
## b[(Intercept) district:5]             0.004 1.000 5210
## b[(Intercept) district:6]             0.003 1.000 5437
## b[(Intercept) district:7]             0.005 1.000 6412
## b[(Intercept) district:8]             0.004 0.999 4445
## b[(Intercept) district:9]             0.004 1.000 6237
## b[(Intercept) district:10]            0.005 1.000 5493
## b[(Intercept) district:11]            0.006 1.000 4584
```

```
## b[(Intercept) district:12]              0.005 1.000 4501
## b[(Intercept) district:13]              0.004 0.999 6217
## b[(Intercept) district:14]              0.004 1.000 3665
## b[(Intercept) district:15]              0.004 0.999 6145
## b[(Intercept) district:16]              0.005 1.000 5244
## b[(Intercept) district:17]              0.004 1.000 5653
## b[(Intercept) district:18]              0.004 1.000 5680
## b[(Intercept) district:19]              0.004 1.000 6254
## b[(Intercept) district:20]              0.005 0.999 6041
## b[(Intercept) district:21]              0.004 0.999 6872
## b[(Intercept) district:22]              0.005 1.000 5425
## b[(Intercept) district:23]              0.005 1.000 5619
## b[(Intercept) district:24]              0.005 0.999 6021
## b[(Intercept) district:25]              0.004 1.000 4466
## b[(Intercept) district:26]              0.005 1.000 5702
## b[(Intercept) district:27]              0.004 0.999 4849
## b[(Intercept) district:28]              0.004 1.000 5076
## b[(Intercept) district:29]              0.004 0.999 7100
## b[(Intercept) district:30]              0.004 1.000 4775
## b[(Intercept) district:31]              0.004 1.000 5526
## b[(Intercept) district:32]              0.005 0.999 5248
## b[(Intercept) district:33]              0.005 1.000 6007
## b[(Intercept) district:34]              0.005 1.000 4176
## b[(Intercept) district:35]              0.003 1.000 6067
## b[(Intercept) district:36]              0.005 1.001 4680
## b[(Intercept) district:37]              0.005 1.000 5444
## b[(Intercept) district:38]              0.005 0.999 6624
## b[(Intercept) district:39]              0.005 0.999 4746
## b[(Intercept) district:40]              0.004 1.000 4888
## b[(Intercept) district:41]              0.004 0.999 5820
## b[(Intercept) district:42]              0.005 1.000 5873
## b[(Intercept) district:43]              0.004 1.000 4915
## b[(Intercept) district:44]              0.004 1.000 6647
## b[(Intercept) district:45]              0.004 1.000 4808
## b[(Intercept) district:46]              0.003 1.000 4686
## b[(Intercept) district:47]              0.005 1.000 4912
## b[(Intercept) district:48]              0.004 1.000 5647
## b[(Intercept) district:49]              0.006 0.999 6431
## b[(Intercept) district:50]              0.005 1.000 5399
## b[(Intercept) district:51]              0.004 1.000 5680
## b[(Intercept) district:52]              0.003 0.999 5515
## b[(Intercept) district:53]              0.005 1.000 5174
## b[(Intercept) district:55]              0.005 1.000 6301
## b[(Intercept) district:56]              0.004 0.999 5361
## b[(Intercept) district:57]              0.005 1.000 5653
## b[(Intercept) district:58]              0.004 0.999 5262
## b[(Intercept) district:59]              0.006 1.000 4746
## b[(Intercept) district:60]              0.004 0.999 5790
## b[(Intercept) district:61]              0.004 0.999 5122
## Sigma[district:(Intercept),(Intercept)] 0.002 1.001 1690
## mean_PPD                                0.000 1.000 4686
## log-posterior                           0.246 1.001 1027
##
## For each parameter, mcse is Monte Carlo standard error, n_eff is a crude measure of effective sample
```

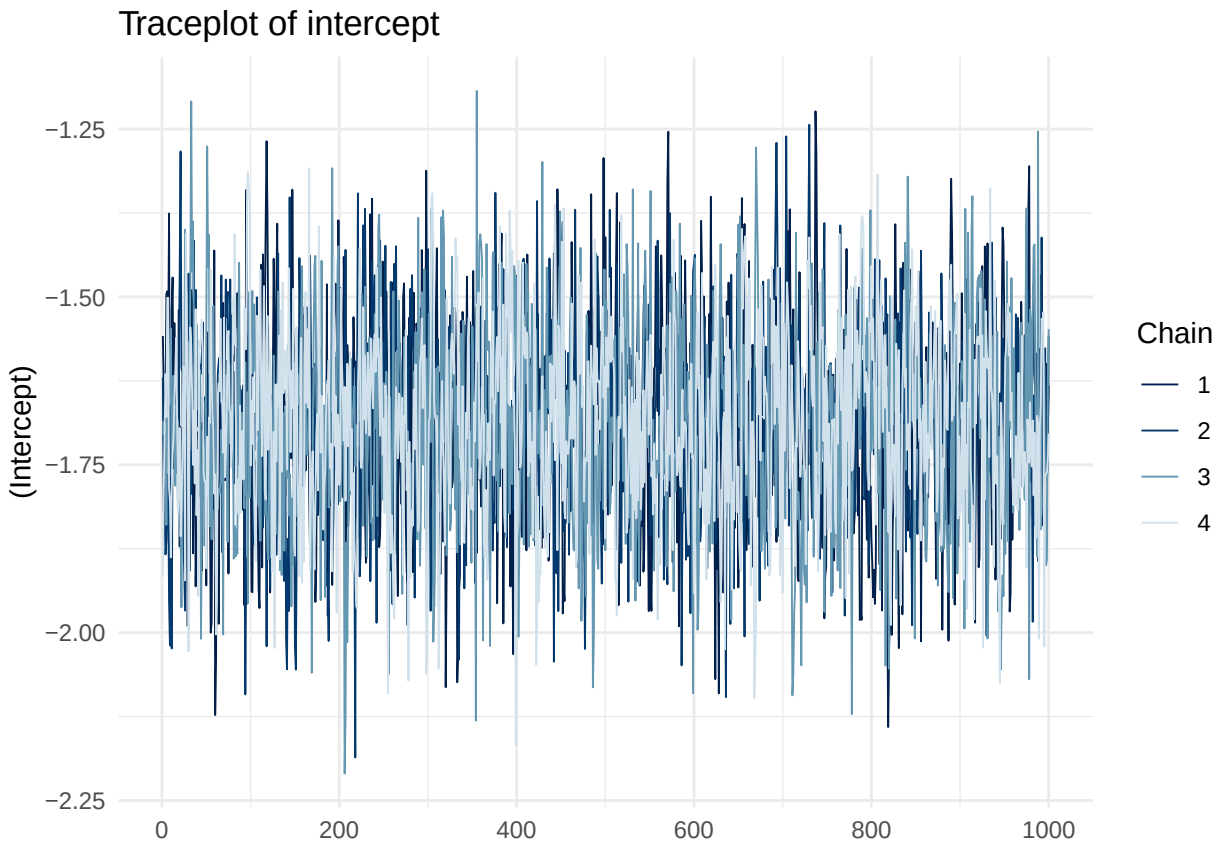
```
summary(varying_intercept_mod,  digits = 3,
        pars=c("(Intercept)", "b[(Intercept) district:1]",
               "b[(Intercept) district:2]", "urbanY", "age", "livch1",
               "livch2", "livch3+",
               "Sigma[district:(Intercept),(Intercept)]"),
        probs = c(0.025, 0.5, 0.975))
```

Plotting

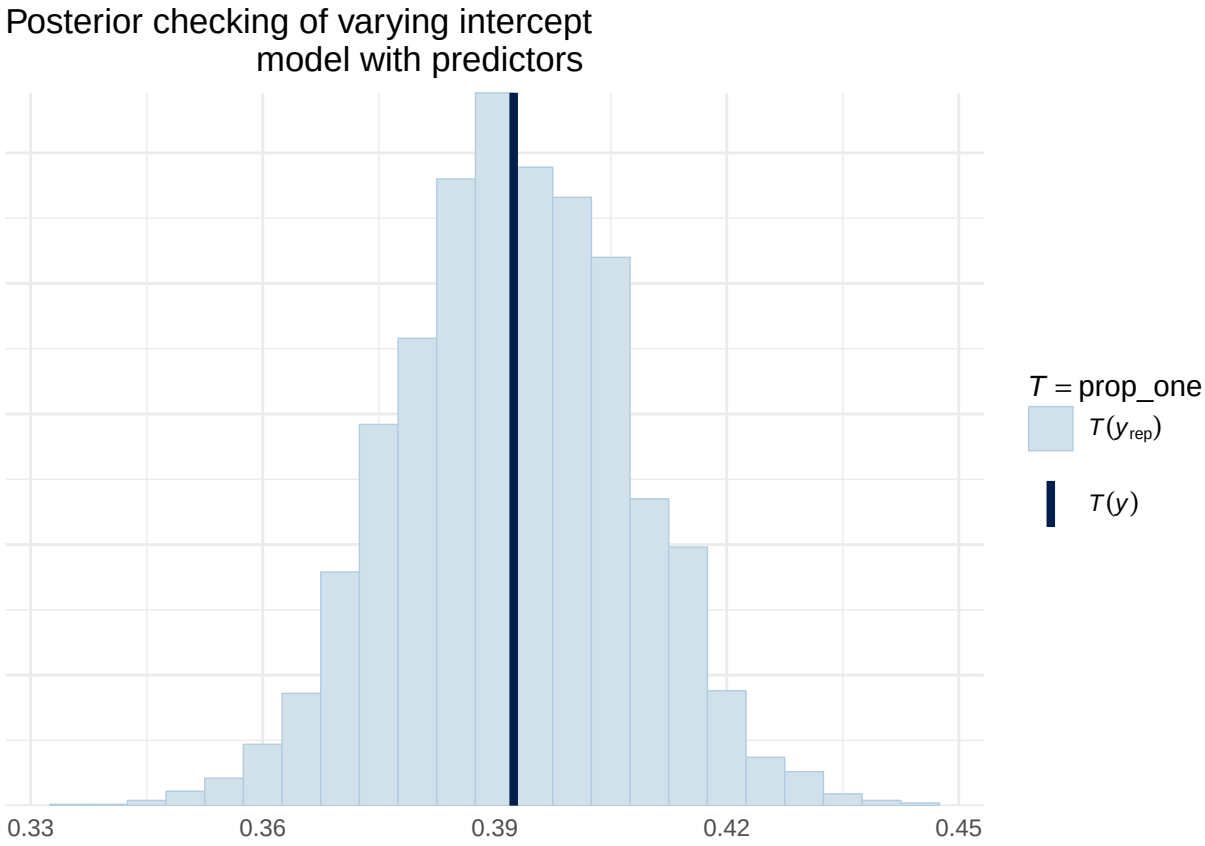
```
plot(varying_intercept_mod, pars=c("(Intercept)", "b[(Intercept) district:1]",
                                   "b[(Intercept) district:2]", "urbanY",
                                   "age", "livch1", "livch2", "livch3+",
                                   "Sigma[district:(Intercept),(Intercept)]")) +
  ggplot2::ggtitle("Posterior medians \n with 50% and 95% intervals")
```




```
plot(varying_intercept_mod, "trace", pars = "(Intercept)") +
  ggplot2::ggtitle("Traceplot of intercept")
```




```
prop_zero_test2 <- pp_check(varying_intercept_mod, plotfun = "stat",
                            stat = "prop_one", binwidth=0.005)
prop_zero_test2 + ggtitle("Posterior checking of varying intercept
                          model with predictors")
```




### Model 3. Varying intercept varying slope model

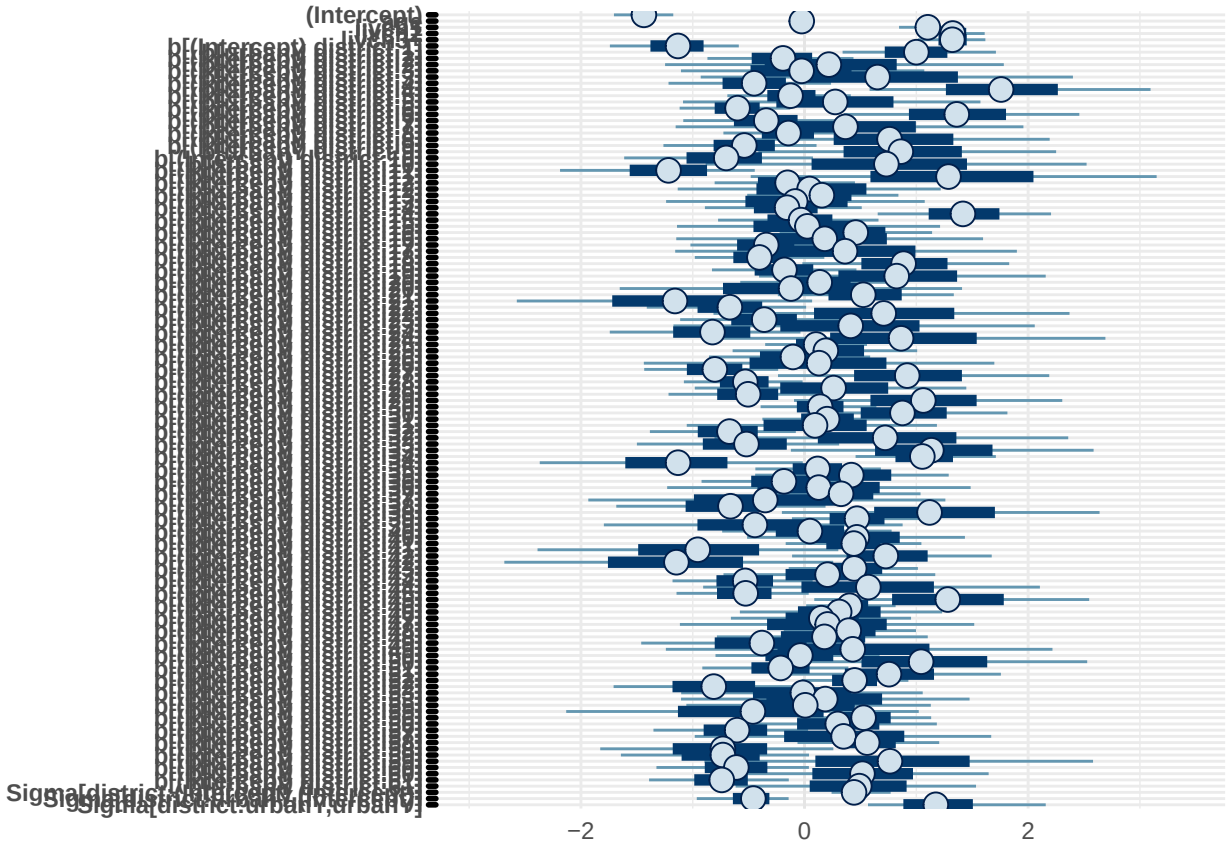
age and livch have the same slope, but allows the slope of urban and intercept to vary among the districts.

```
varying_inter_slope_mod <- stan_glmer(formula = use ~ 1 + age + livch + (urban|district),
                          data = cont,
                          seed = 271,
                          cores = getOption("mc.cores", 4L),
                          family = binomial(link = "logit"))
```

```
prior_summary(varying_inter_slope_mod)
```

```
## Priors for model 'varying_inter_slope_mod'
## ------
## Intercept (after predictors centered)
##  ~ normal(location = 0, scale = 10)
##
## Coefficients
##   Specified prior:
##     ~ normal(location = [0,0,0,...], scale = [2.5,2.5,2.5,...])
##   Adjusted prior:
##     ~ normal(location = [0,0,0,...], scale = [0.28,2.50,2.50,...])
##
## Covariance
##  ~ decov(reg. = 1, conc. = 1, shape = 1, scale = 1)
## ------
## See help('prior_summary.stanreg') for more details
```

```
plot(varying_inter_slope_mod)
```




```
summary(varying_inter_slope_mod, digits = 3)
```

```
##
## Model Info:
##  function:     stan_glmer
##  family:       binomial [logit]
##  formula:      use ~ 1 + age + livch + (urban | district)
##  algorithm:    sampling
##  sample:       4000 (posterior sample size)
##  priors:       see help('prior_summary')
##  observations: 1934
##  groups:       district (60)
##
## Estimates:
##                                    mean   sd     10%    50%    90%
## (Intercept)                       -1.438  0.159 -1.644 -1.437 -1.234
## age                               -0.025  0.008 -0.035 -0.025 -0.015
## livch1                             1.106  0.158  0.904  1.103  1.309
## livch2                             1.326  0.176  1.100  1.325  1.549
## livch3+                            1.322  0.182  1.086  1.322  1.559
## b[(Intercept) district:1]         -1.144  0.352 -1.598 -1.132 -0.697
## b[urbanY district:1]               1.007  0.418  0.496  1.000  1.555
## b[(Intercept) district:2]         -0.202  0.396 -0.710 -0.193  0.294
## b[urbanY district:2]               0.238  0.934 -0.928  0.218  1.405
## b[(Intercept) district:3]         -0.031  0.679 -0.886 -0.026  0.817
```

```
## b[urbanY district:3]                0.705  1.024 -0.558  0.653  2.041
## b[(Intercept) district:4]          -0.458  0.436 -1.017 -0.451  0.091
## b[urbanY district:4]                1.786  0.756  0.849  1.758  2.754
## b[(Intercept) district:5]          -0.125  0.335 -0.562 -0.125  0.294
## b[urbanY district:5]                0.270  0.816 -0.752  0.275  1.283
## b[(Intercept) district:6]          -0.608  0.300 -1.001 -0.599 -0.227
## b[urbanY district:6]                1.377  0.645  0.557  1.362  2.204
## b[(Intercept) district:7]          -0.357  0.434 -0.927 -0.342  0.188
## b[urbanY district:7]                0.383  0.954 -0.752  0.366  1.584
## b[(Intercept) district:8]          -0.151  0.348 -0.597 -0.144  0.301
## b[urbanY district:8]                0.812  0.810 -0.200  0.760  1.878
## b[(Intercept) district:9]          -0.546  0.416 -1.080 -0.539 -0.019
## b[urbanY district:9]                0.885  0.810 -0.142  0.861  1.920
## b[(Intercept) district:10]         -0.727  0.517 -1.394 -0.700 -0.078
## b[urbanY district:10]               0.762  1.044 -0.520  0.732  2.114
## b[(Intercept) district:11]         -1.244  0.533 -1.936 -1.217 -0.595
## b[urbanY district:11]               1.318  1.122 -0.095  1.288  2.708
## b[(Intercept) district:12]         -0.163  0.386 -0.659 -0.152  0.328
## b[urbanY district:12]               0.057  0.730 -0.886  0.045  0.987
## b[(Intercept) district:13]          0.153  0.414 -0.370  0.155  0.681
## b[urbanY district:13]              -0.079  0.699 -0.964 -0.083  0.807
## b[(Intercept) district:14]         -0.171  0.426 -0.730 -0.156  0.366
## b[urbanY district:14]               1.425  0.469  0.839  1.417  2.023
## b[(Intercept) district:15]         -0.041  0.439 -0.616 -0.031  0.515
## b[urbanY district:15]               0.028  0.719 -0.869  0.026  0.954
## b[(Intercept) district:16]          0.459  0.411 -0.060  0.458  0.966
## b[urbanY district:16]               0.194  0.840 -0.856  0.181  1.240
## b[(Intercept) district:17]         -0.351  0.390 -0.860 -0.342  0.140
## b[urbanY district:17]               0.371  0.940 -0.794  0.362  1.555
## b[(Intercept) district:18]         -0.402  0.357 -0.850 -0.404  0.057
## b[urbanY district:18]               0.897  0.568  0.188  0.886  1.623
## b[(Intercept) district:19]         -0.183  0.393 -0.694 -0.179  0.328
## b[urbanY district:19]               0.843  0.790 -0.158  0.824  1.832
## b[(Intercept) district:20]          0.129  0.423 -0.414  0.136  0.656
## b[urbanY district:20]              -0.121  0.941 -1.297 -0.121  1.078
## b[(Intercept) district:21]          0.540  0.486 -0.078  0.526  1.165
## b[urbanY district:21]              -1.198  0.808 -2.246 -1.159 -0.186
## b[(Intercept) district:22]         -0.679  0.436 -1.254 -0.668 -0.121
## b[urbanY district:22]               0.730  0.966 -0.481  0.708  1.998
## b[(Intercept) district:23]         -0.370  0.444 -0.944 -0.361  0.191
## b[urbanY district:23]               0.413  0.983 -0.825  0.413  1.691
## b[(Intercept) district:24]         -0.849  0.520 -1.505 -0.824 -0.209
## b[urbanY district:24]               0.906  1.033 -0.361  0.863  2.273
## b[(Intercept) district:25]          0.108  0.279 -0.253  0.103  0.464
## b[urbanY district:25]               0.190  0.501 -0.453  0.191  0.827
## b[(Intercept) district:26]         -0.112  0.439 -0.667 -0.104  0.444
## b[urbanY district:26]               0.126  0.948 -1.050  0.130  1.333
## b[(Intercept) district:27]         -0.813  0.368 -1.289 -0.802 -0.352
## b[urbanY district:27]               0.937  0.742  0.014  0.919  1.895
## b[(Intercept) district:28]         -0.536  0.324 -0.953 -0.530 -0.119
## b[urbanY district:28]               0.252  0.745 -0.671  0.260  1.194
## b[(Intercept) district:29]         -0.515  0.412 -1.048 -0.504  0.005
## b[urbanY district:29]               1.072  0.714  0.162  1.063  1.996
## b[(Intercept) district:30]          0.135  0.310 -0.268  0.139  0.530
```

```
## b[urbanY district:30]                0.897  0.552  0.197  0.876  1.623
## b[(Intercept) district:31]           0.202  0.349 -0.242  0.202  0.654
## b[urbanY district:31]                0.086  0.685 -0.781  0.094  0.950
## b[(Intercept) district:32]          -0.692  0.400 -1.226 -0.672 -0.197
## b[urbanY district:32]                0.735  0.957 -0.458  0.721  1.979
## b[(Intercept) district:33]          -0.548  0.556 -1.271 -0.519  0.140
## b[urbanY district:33]                1.171  0.813  0.153  1.135  2.225
## b[(Intercept) district:34]           1.072  0.383  0.584  1.054  1.568
## b[urbanY district:34]               -1.155  0.708 -2.064 -1.131 -0.282
## b[(Intercept) district:35]           0.118  0.341 -0.301  0.117  0.554
## b[urbanY district:35]                0.415  0.532 -0.267  0.418  1.102
## b[(Intercept) district:36]          -0.190  0.436 -0.771 -0.184  0.361
## b[urbanY district:36]                0.122  0.825 -0.922  0.127  1.168
## b[(Intercept) district:37]           0.322  0.438 -0.240  0.327  0.887
## b[urbanY district:37]               -0.342  0.976 -1.562 -0.351  0.906
## b[(Intercept) district:38]          -0.697  0.577 -1.436 -0.663  0.009
## b[urbanY district:38]                1.168  0.840  0.126  1.118  2.283
## b[(Intercept) district:39]           0.472  0.368  0.010  0.469  0.947
## b[urbanY district:39]               -0.449  0.802 -1.458 -0.444  0.567
## b[(Intercept) district:40]           0.041  0.459 -0.554  0.048  0.615
## b[urbanY district:40]                0.465  0.583 -0.271  0.468  1.208
## b[(Intercept) district:41]           0.442  0.366 -0.027  0.441  0.904
## b[urbanY district:41]               -0.976  0.819 -2.050 -0.955  0.039
## b[(Intercept) district:42]           0.743  0.546  0.071  0.727  1.438
## b[urbanY district:42]               -1.175  0.894 -2.331 -1.146 -0.076
## b[(Intercept) district:43]           0.445  0.356 -0.009  0.444  0.903
## b[urbanY district:43]                0.213  0.574 -0.509  0.206  0.941
## b[(Intercept) district:44]          -0.539  0.381 -1.028 -0.531 -0.054
## b[urbanY district:44]                0.575  0.930 -0.572  0.571  1.745
## b[(Intercept) district:45]          -0.541  0.362 -1.012 -0.527 -0.084
## b[urbanY district:45]                1.296  0.739  0.375  1.281  2.241
## b[(Intercept) district:46]           0.406  0.244  0.103  0.403  0.721
## b[urbanY district:46]                0.314  0.553 -0.387  0.310  1.014
## b[(Intercept) district:47]           0.155  0.486 -0.470  0.150  0.772
## b[urbanY district:47]                0.201  0.811 -0.809  0.207  1.261
## b[(Intercept) district:48]           0.401  0.359 -0.056  0.395  0.867
## b[urbanY district:48]                0.167  0.570 -0.579  0.178  0.884
## b[(Intercept) district:49]          -0.407  0.609 -1.193 -0.381  0.353
## b[urbanY district:49]                0.453  1.056 -0.853  0.431  1.835
## b[(Intercept) district:50]          -0.050  0.455 -0.634 -0.037  0.521
## b[urbanY district:50]                1.084  0.848  0.023  1.043  2.190
## b[(Intercept) district:51]          -0.226  0.395 -0.737 -0.214  0.271
## b[urbanY district:51]                0.759  0.601 -0.011  0.755  1.541
## b[(Intercept) district:52]           0.448  0.294  0.071  0.448  0.824
## b[urbanY district:52]               -0.817  0.538 -1.516 -0.812 -0.132
## b[(Intercept) district:53]          -0.022  0.662 -0.858 -0.015  0.825
## b[urbanY district:53]                0.182  0.781 -0.822  0.186  1.174
## b[(Intercept) district:55]           0.020  0.676 -0.795  0.007  0.871
## b[urbanY district:55]               -0.499  0.959 -1.747 -0.462  0.704
## b[(Intercept) district:56]           0.531  0.366  0.062  0.528  1.001
## b[urbanY district:56]                0.299  0.535 -0.378  0.297  0.960
## b[(Intercept) district:57]          -0.625  0.424 -1.181 -0.603 -0.098
## b[urbanY district:57]                0.348  0.807 -0.680  0.349  1.366
## b[(Intercept) district:58]           0.562  0.384  0.070  0.560  1.055
```

```
## b[urbanY district:58]                    -0.756  0.628 -1.586 -0.730  0.033
## b[(Intercept) district:59]               -0.763  0.522 -1.432 -0.731 -0.132
## b[urbanY district:59]                     0.807  1.073 -0.501  0.764  2.163
## b[(Intercept) district:60]               -0.621  0.417 -1.159 -0.610 -0.100
## b[urbanY district:60]                     0.523  0.673 -0.345  0.518  1.399
## b[(Intercept) district:61]               -0.751  0.377 -1.236 -0.741 -0.275
## b[urbanY district:61]                     0.478  0.653 -0.368  0.490  1.303
## Sigma[district:(Intercept),(Intercept)]  0.466  0.166  0.282  0.443  0.680
## Sigma[district:urbanY,(Intercept)]      -0.495  0.261 -0.823 -0.458 -0.203
## Sigma[district:urbanY,urbanY]            1.244  0.517  0.679  1.174  1.886
##
## Fit Diagnostics:
##            mean   sd    10%   50%   90%
## mean_PPD 0.392  0.014 0.374 0.392 0.411
##
## The mean_ppd is the sample average posterior predictive distribution of the outcome variable (for de
##
## MCMC diagnostics
##                                         mcse  Rhat  n_eff
## (Intercept)                             0.004 1.002 1262
## age                                     0.000 1.001 3493
## livch1                                  0.003 1.000 3552
## livch2                                  0.003 1.001 2932
## livch3+                                 0.004 1.001 2526
## b[(Intercept) district:1]               0.006 1.000 3212
## b[urbanY district:1]                    0.006 1.000 5024
## b[(Intercept) district:2]               0.007 1.001 3376
## b[urbanY district:2]                    0.012 1.000 5614
## b[(Intercept) district:3]               0.009 1.001 5313
## b[urbanY district:3]                    0.014 0.999 5188
## b[(Intercept) district:4]               0.009 1.002 2154
## b[urbanY district:4]                    0.012 0.999 3716
## b[(Intercept) district:5]               0.006 1.001 3541
## b[urbanY district:5]                    0.011 1.000 5962
## b[(Intercept) district:6]               0.006 1.001 2166
## b[urbanY district:6]                    0.009 0.999 5456
## b[(Intercept) district:7]               0.006 1.001 4606
## b[urbanY district:7]                    0.015 1.000 4136
## b[(Intercept) district:8]               0.006 1.001 3431
## b[urbanY district:8]                    0.012 1.000 4918
## b[(Intercept) district:9]               0.008 1.001 2944
## b[urbanY district:9]                    0.012 1.000 4209
## b[(Intercept) district:10]              0.008 1.000 4071
## b[urbanY district:10]                   0.018 1.000 3215
## b[(Intercept) district:11]              0.011 1.001 2487
## b[urbanY district:11]                   0.026 1.002 1792
## b[(Intercept) district:12]              0.006 1.000 4537
## b[urbanY district:12]                   0.010 1.000 5626
## b[(Intercept) district:13]              0.005 1.000 5744
## b[urbanY district:13]                   0.009 0.999 6636
## b[(Intercept) district:14]              0.009 1.001 2377
## b[urbanY district:14]                   0.007 1.000 3927
## b[(Intercept) district:15]              0.006 0.999 5128
## b[urbanY district:15]                   0.009 0.999 6569
```

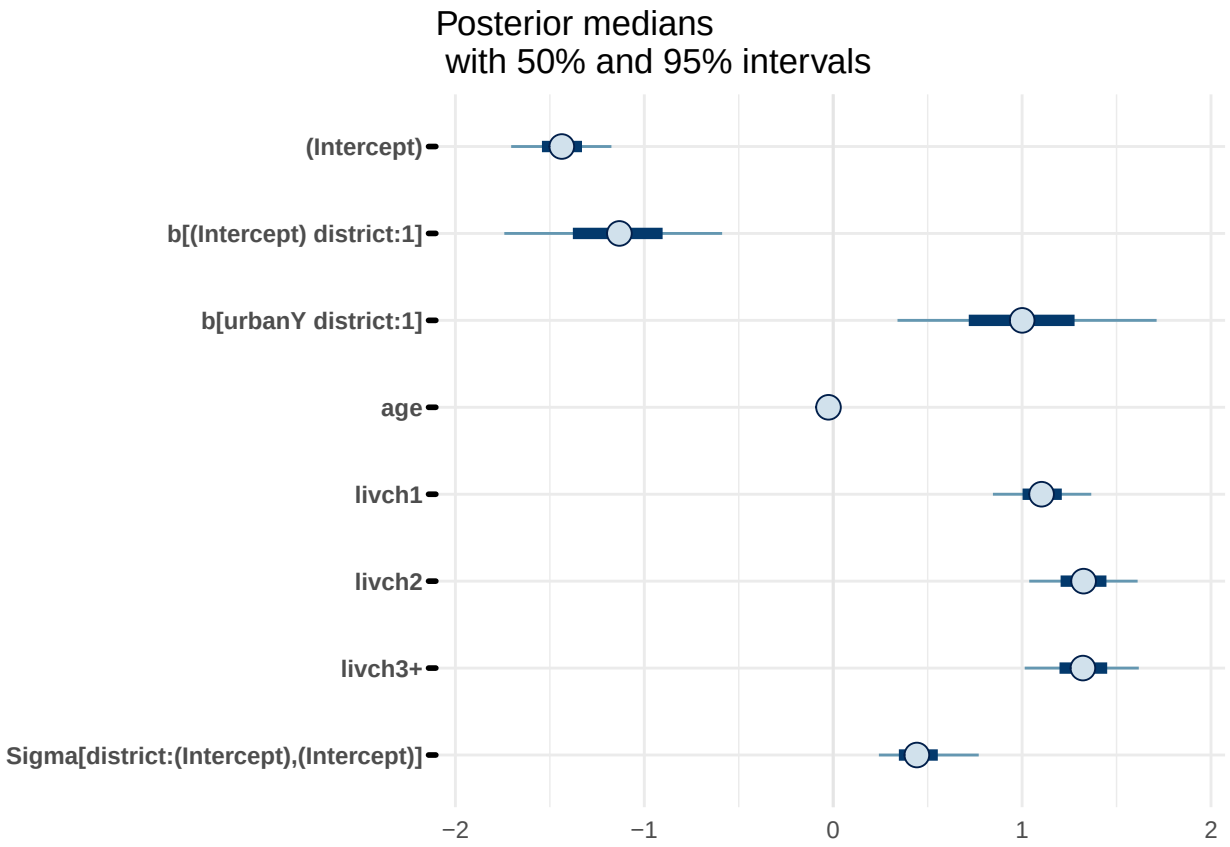
```
## b[(Intercept) district:16]             0.006 1.001 5138
## b[urbanY district:16]                  0.012 0.999 5245
## b[(Intercept) district:17]             0.006 1.000 4158
## b[urbanY district:17]                  0.014 1.000 4716
## b[(Intercept) district:18]             0.006 1.002 3484
## b[urbanY district:18]                  0.007 1.000 5872
## b[(Intercept) district:19]             0.007 1.000 3583
## b[urbanY district:19]                  0.011 1.000 4796
## b[(Intercept) district:20]             0.006 1.000 4461
## b[urbanY district:20]                  0.011 0.999 6735
## b[(Intercept) district:21]             0.007 1.000 5269
## b[urbanY district:21]                  0.013 1.001 3821
## b[(Intercept) district:22]             0.006 1.000 4724
## b[urbanY district:22]                  0.017 1.001 3413
## b[(Intercept) district:23]             0.007 1.000 4472
## b[urbanY district:23]                  0.015 1.000 4193
## b[(Intercept) district:24]             0.009 1.000 3515
## b[urbanY district:24]                  0.019 1.001 3012
## b[(Intercept) district:25]             0.005 1.000 2989
## b[urbanY district:25]                  0.006 1.000 6057
## b[(Intercept) district:26]             0.006 0.999 4712
## b[urbanY district:26]                  0.013 1.000 5469
## b[(Intercept) district:27]             0.006 1.000 3294
## b[urbanY district:27]                  0.011 1.000 4227
## b[(Intercept) district:28]             0.005 1.000 3982
## b[urbanY district:28]                  0.012 1.000 4032
## b[(Intercept) district:29]             0.007 1.000 3171
## b[urbanY district:29]                  0.010 0.999 5193
## b[(Intercept) district:30]             0.006 1.001 2526
## b[urbanY district:30]                  0.007 1.000 5962
## b[(Intercept) district:31]             0.006 1.000 3713
## b[urbanY district:31]                  0.010 1.000 5116
## b[(Intercept) district:32]             0.007 1.000 3735
## b[urbanY district:32]                  0.016 1.000 3400
## b[(Intercept) district:33]             0.010 1.001 3149
## b[urbanY district:33]                  0.011 1.000 5383
## b[(Intercept) district:34]             0.005 1.001 5341
## b[urbanY district:34]                  0.011 0.999 4520
## b[(Intercept) district:35]             0.005 1.000 4866
## b[urbanY district:35]                  0.006 0.999 7500
## b[(Intercept) district:36]             0.006 1.000 5881
## b[urbanY district:36]                  0.011 1.000 5360
## b[(Intercept) district:37]             0.006 1.000 5603
## b[urbanY district:37]                  0.013 1.000 5343
## b[(Intercept) district:38]             0.011 1.000 2574
## b[urbanY district:38]                  0.013 1.000 4173
## b[(Intercept) district:39]             0.005 0.999 5420
## b[urbanY district:39]                  0.010 0.999 5865
## b[(Intercept) district:40]             0.007 1.000 4491
## b[urbanY district:40]                  0.008 0.999 5736
## b[(Intercept) district:41]             0.005 1.000 4858
## b[urbanY district:41]                  0.012 1.000 4483
## b[(Intercept) district:42]             0.009 1.001 4047
## b[urbanY district:42]                  0.014 1.000 3978
```

```
## b[(Intercept) district:43]                0.005 1.000 4351
## b[urbanY district:43]                     0.007 0.999 6713
## b[(Intercept) district:44]                0.006 1.001 4175
## b[urbanY district:44]                     0.015 1.000 4024
## b[(Intercept) district:45]                0.007 1.000 2824
## b[urbanY district:45]                     0.012 1.000 4093
## b[(Intercept) district:46]                0.004 1.000 2984
## b[urbanY district:46]                     0.007 1.000 6191
## b[(Intercept) district:47]                0.006 1.000 5792
## b[urbanY district:47]                     0.010 1.000 6332
## b[(Intercept) district:48]                0.005 1.000 4300
## b[urbanY district:48]                     0.008 1.000 5625
## b[(Intercept) district:49]                0.009 1.001 5037
## b[urbanY district:49]                     0.017 1.000 3955
## b[(Intercept) district:50]                0.008 1.000 3308
## b[urbanY district:50]                     0.013 1.000 4416
## b[(Intercept) district:51]                0.008 1.002 2659
## b[urbanY district:51]                     0.008 1.000 5953
## b[(Intercept) district:52]                0.004 1.002 4701
## b[urbanY district:52]                     0.006 1.000 7207
## b[(Intercept) district:53]                0.009 1.000 5784
## b[urbanY district:53]                     0.010 1.000 5759
## b[(Intercept) district:55]                0.010 1.000 4716
## b[urbanY district:55]                     0.014 1.000 4985
## b[(Intercept) district:56]                0.006 1.000 4234
## b[urbanY district:56]                     0.007 0.999 6497
## b[(Intercept) district:57]                0.006 1.000 4413
## b[urbanY district:57]                     0.012 1.001 4615
## b[(Intercept) district:58]                0.006 1.000 4726
## b[urbanY district:58]                     0.008 1.000 5492
## b[(Intercept) district:59]                0.008 1.000 4295
## b[urbanY district:59]                     0.019 1.001 3145
## b[(Intercept) district:60]                0.006 1.001 4198
## b[urbanY district:60]                     0.010 1.000 5006
## b[(Intercept) district:61]                0.006 0.999 4558
## b[urbanY district:61]                     0.009 0.999 5176
## Sigma[district:(Intercept),(Intercept)] 0.005 1.001 1232
## Sigma[district:urbanY,(Intercept)]      0.010 1.007  704
## Sigma[district:urbanY,urbanY]           0.016 1.003 1048
## mean_PPD                                0.000 1.000 4193
## log-posterior                           0.359 1.002  971
##
## For each parameter, mcse is Monte Carlo standard error, n_eff is a crude measure of effective sample
```

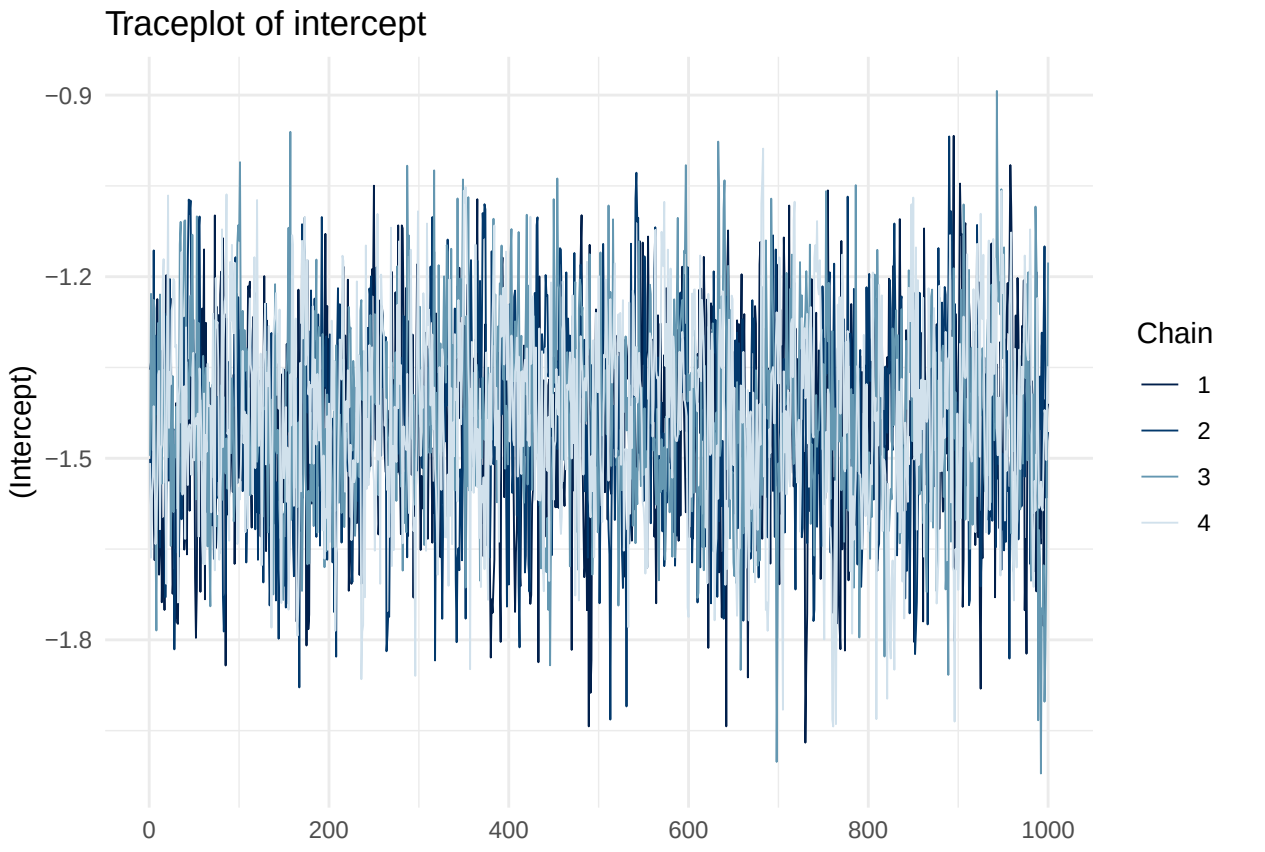
```
summary(varying_inter_slope_mod,  digits = 3,
        pars=c("(Intercept)", "b[(Intercept) district:1]",
               "b[urbanY district:1]", "age", "livch1", "livch2",
               "livch3+","Sigma[district:(Intercept),(Intercept)]"),
        probs = c(0.025, 0.5, 0.975))
```

```
plot(varying_inter_slope_mod, pars=c("(Intercept)",
                                     "b[(Intercept) district:1]",
                                     "b[urbanY district:1]", "age",
                                     "livch1", "livch2", "livch3+",
                                     "Sigma[district:(Intercept),(Intercept)]")) +
```

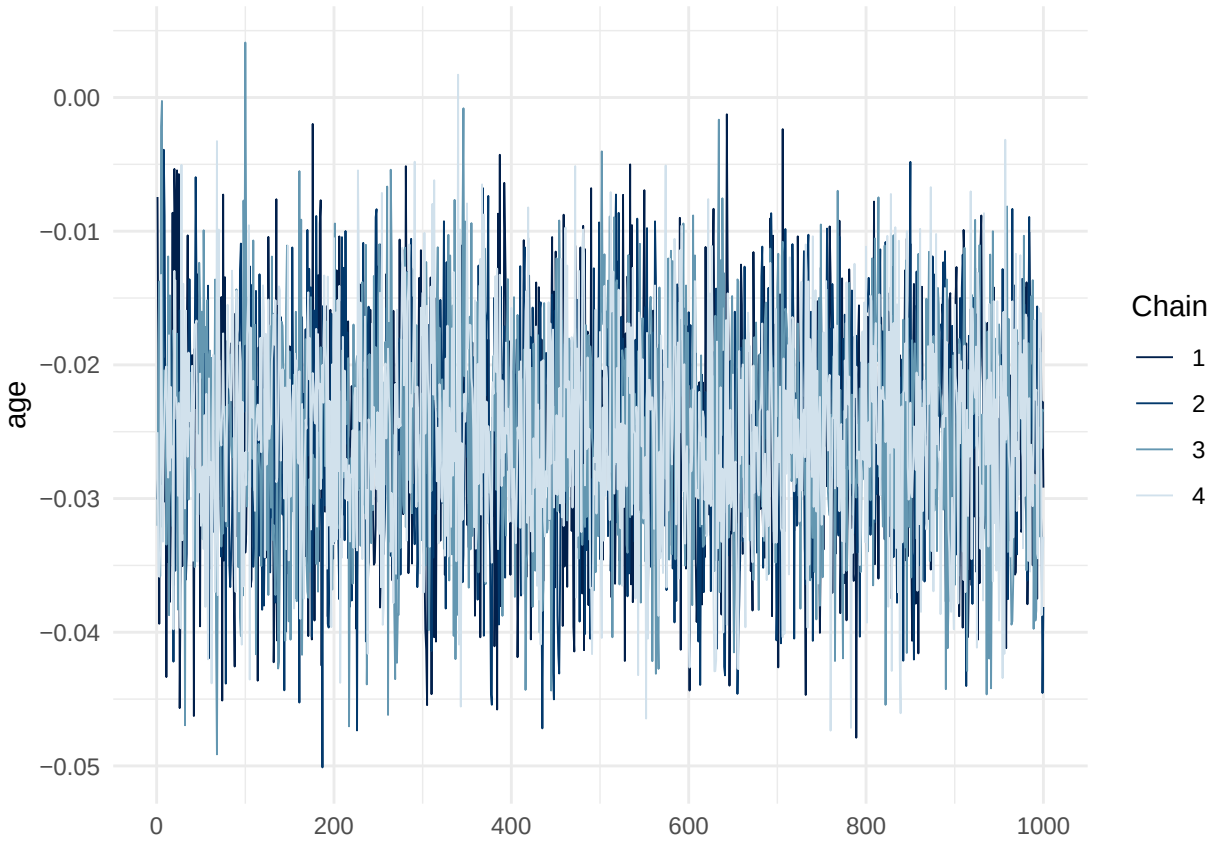
```
  ggplot2::ggtitle("Posterior medians \n with 50% and 95% intervals")
```




```
plot(varying_inter_slope_mod, "trace", pars = "(Intercept)") + ggplot2::ggtitle("Traceplot of intercept
```



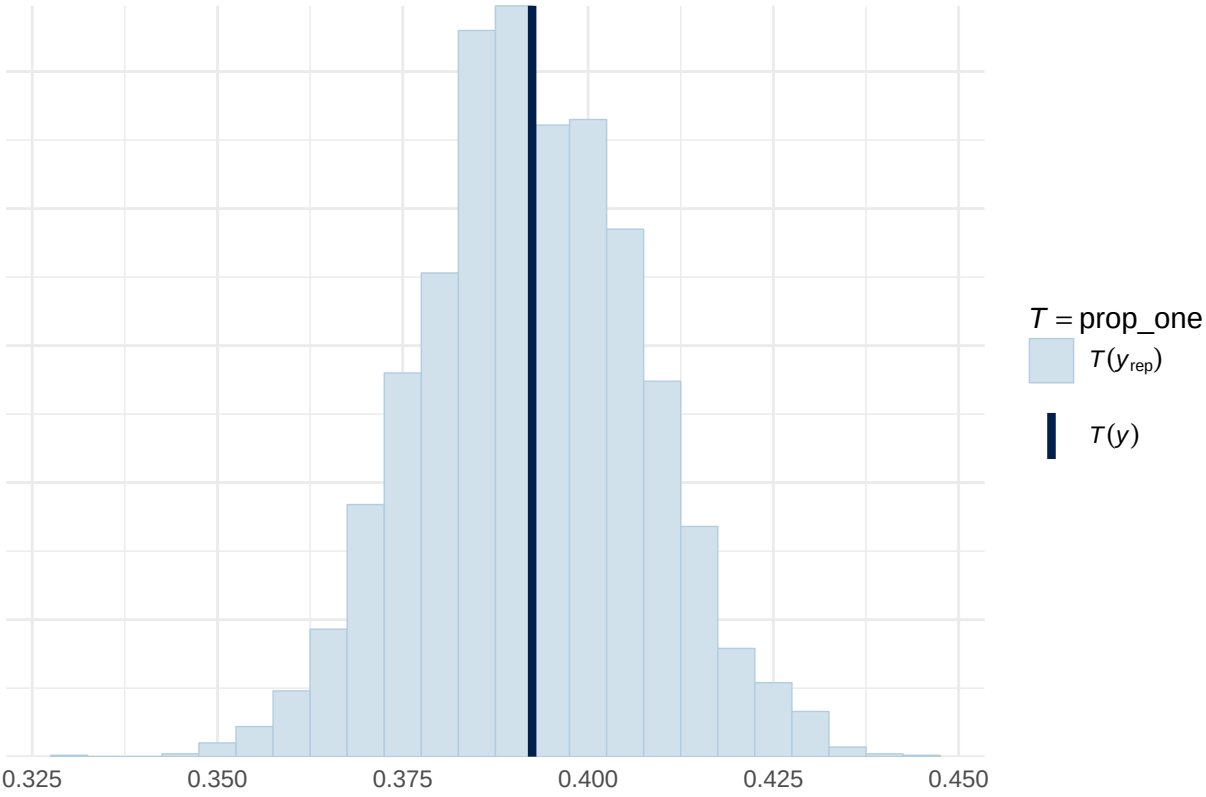

```
plot(varying_inter_slope_mod, "trace", pars = "age")
```




Posterior checking

```
yrep_mod3 <- posterior_predict(varying_inter_slope_mod, draws = 2000)
# mean(ytrue)
# hist(apply(yrep_mod3, 1, mean))

prop_one <- function(y) mean(y == 1)
prop_zero_test3 <- pp_check(varying_inter_slope_mod,
                            plotfun = "stat", stat = "prop_one", binwidth=0.005)
prop_zero_test3 + ggtitle("Posterior checking of varying intercept varying slope model")
```




## 3. Model comparison

```
varying_inter_nopred_mod$waic <- rstanarm::waic(varying_inter_nopred_mod)
varying_intercept_mod$waic <- rstanarm::waic(varying_intercept_mod)
varying_inter_slope_mod$waic <- rstanarm::waic(varying_inter_slope_mod)

varying_inter_nopred_mod$loo <- rstanarm::loo(varying_inter_nopred_mod,
                                              cores = getOption("mc.cores", 4))
varying_intercept_mod$loo <- rstanarm::loo(varying_intercept_mod,
                                           cores = getOption("mc.cores", 4))
varying_inter_slope_mod$loo <- rstanarm::loo(varying_inter_slope_mod,
                                             cores = getOption("mc.cores", 4))

loo_compare(varying_inter_nopred_mod, varying_intercept_mod, varying_inter_slope_mod,
            criterion =  "loo")
```

```
## Model comparison based on LOO-CV:
##                           elpd_diff se_diff
## varying_inter_slope_mod    0.0       0.0
## varying_intercept_mod     -6.3       6.5
## varying_inter_nopred_mod -59.5      10.8
```

```
loo_compare(varying_inter_nopred_mod, varying_intercept_mod, varying_inter_slope_mod,
            criterion =  "waic")
```

```
## Model comparison based on WAIC:
```

```
##                           elpd_diff se_diff
## varying_inter_slope_mod    0.0       0.0
## varying_intercept_mod     -6.5       6.5
## varying_inter_nopred_mod -59.8      10.8
```

```
model_list <- stanreg_list(varying_inter_nopred_mod, varying_intercept_mod, varying_inter_slope_mod)
loo_model_weights(model_list)
```

```
## Method: stacking
## ------
##                           weight
## varying_inter_nopred_mod 0.000
## varying_intercept_mod    0.342
## varying_inter_slope_mod  0.658
```

Bayesian model averaging (not contained in the final report)

```
fit1 <- brm(formula = use ~ 1 + urban + age + livch + (1|district),
                          data = cont,
                          seed = 271,
                          cores = getOption("mc.cores", 4L),
                          family = bernoulli(link = "logit"))
summary(fit1)

fit2 <- brm(formula = use ~ 1 + age + livch + (urban|district),
                          data = cont,
                          seed = 271,
                          cores = getOption("mc.cores", 4L),
                          family = bernoulli(link = "logit"))
summary(fit2)
avg_pred <- pp_average(fit1, fit2)
```