Generalized Linear Mixed Models

Contents

Read in the individual data (or a pairwise dataset)

```
library(tidyr)
library(dplyr)

#install.packages("lme4")
library(lme4)

acitelli_ind <- read.csv("/Users/randigarcia/Desktop/Data/acitelli.csv", header=TRUE)
```

Convert individual data to pairwise. I also create a simhobs variable that will be our binary response, two dummy variables that will be useful for estimating separate random intercepts for men and women, and a count variable `cigarettes`.

```
tempA <- acitelli_ind %>%
  mutate(genderE = gender, partnum = 1) %>%
  mutate(gender = ifelse(gender == 1, "A", "P")) %>%
  gather(variable, value, self_pos:genderE) %>%
  unite(var_gender, variable, gender) %>%
  spread(var_gender, value)

tempB <- acitelli_ind %>%
  mutate(genderE = gender, partnum = 2) %>%
  mutate(gender = ifelse(gender == 1, "P", "A")) %>%
  gather(variable, value, self_pos:genderE)%>%
  unite(var_gender, variable, gender) %>%
  spread(var_gender, value)
```

```
acitelli_pair <- bind_rows(tempA, tempB) %>%
  arrange(cuplid) %>%
  mutate(gender_A = ifelse(genderE_A == 1, "hus", "wife"),
         gender_A = as.factor(gender_A),
         simhob_bin_A = ifelse(simhob_A == 1, 1, 0), #forced binary variable
         man = ifelse(genderE_A == 1, 1, 0),
         woman = ifelse(genderE_A == 1, 0, 1),
         cigarettes_A = rpois(296, 0.7)) %>%
  group_by(cuplid) %>%
  mutate(cupcig = rpois(1, 0.7)) %>%
  ungroup(cuplid) %>%
  mutate(cigarettes_A = cigarettes_A + cupcig)

rm(tempA, tempB)
```

Logistic Multilevel Modeling (Binary variables)

To account for the nonindependence, we can make use of the `glmer()` function from the `lme4` package. Note that we are asking for the variance of intercepts across dyads, that is the random intercept in traditional multilevel modeling. The `gls()` function in the `nlme` package does not have an option for specifying a link function (i.e., there is no `family =` option). The syntax of `glmer()` differs a bit from `gls()` in that the random effects are specified within the formula: `+ (1/cuplid)`.

Indistinguishable Dyads

```
apim_bin <- glmer(simhob_bin_A ~ other_pos_A + other_pos_P
                  + (1|cuplid),
                  data = acitelli_pair,
                  family = binomial,
                  na.action = na.omit)

summary(apim_bin)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: simhob_bin_A ~ other_pos_A + other_pos_P + (1 | cuplid)
##    Data: acitelli_pair
##
##      AIC      BIC   logLik deviance df.resid
```

```
##    322.5    337.3   -157.3    314.5      292
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -0.90316 -0.44848 -0.33245  0.02569  2.03565
##
## Random effects:
##  Groups Name        Variance Std.Dev.
##  cuplid (Intercept) 1.659    1.288
## Number of obs: 296, groups:  cuplid, 148
##
## Fixed effects:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  -8.3310     2.4903  -3.345 0.000821 ***
## other_pos_A   0.9195     0.3894   2.361 0.018217 *
## other_pos_P   0.6723     0.3756   1.790 0.073481 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) oth__A
## other_pos_A -0.738
## other_pos_P -0.708  0.058
```

Distinguishable Dyads

Interaction approach.

```
apim_bin_di <- glmer(simhob_bin_A ~ other_pos_A + other_pos_P + genderE_A
                     + other_pos_A*genderE_A + other_pos_P*genderE_A
                     + (man + woman - 1|cuplid),
                     data = acitelli_pair,
                     family = binomial,
                     na.action = na.omit)

summary(apim_bin_di)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula:
## simhob_bin_A ~ other_pos_A + other_pos_P + genderE_A + other_pos_A *
##     genderE_A + other_pos_P * genderE_A + (man + woman - 1 |      cuplid)
##    Data: acitelli_pair
```

```
##
##      AIC      BIC   logLik deviance df.resid
##    314.7    347.9   -148.4    296.7      287
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.09016 -0.48698 -0.00949  0.03293  2.52186
##
## Random effects:
##  Groups Name  Variance Std.Dev. Corr
##  cuplid man   183.8755 13.5601
##         woman   0.1908  0.4368  1.00
## Number of obs: 296, groups:  cuplid, 148
##
## Fixed effects:
##                       Estimate Std. Error z value Pr(>|z|)
## (Intercept)            -38.413     15.095  -2.545   0.0109 *
## other_pos_A              6.104      2.453   2.489   0.0128 *
## other_pos_P              1.433      2.551   0.562   0.5744
## genderE_A              -30.611     14.859  -2.060   0.0394 *
## other_pos_A:genderE_A    5.014      2.462   2.037   0.0417 *
## other_pos_P:genderE_A    0.937      2.559   0.366   0.7142
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) oth__A oth__P gndE_A o__A:E
## other_pos_A -0.656
## other_pos_P -0.683 -0.098
## genderE_A    0.988 -0.647 -0.675
## othr__A:E_A -0.635  0.985 -0.113 -0.643
## othr__P:E_A -0.662 -0.114  0.986 -0.670 -0.134
## convergence code: 0
## unable to evaluate scaled gradient
## Model failed to converge: degenerate  Hessian with 2 negative eigenvalues
```

Two-intercept model.

```
#does not converge
apim_bin_di_two <- glmer(simhob_bin_A ~ gender_A + other_pos_A:gender_A + other_pos_P:ge
                         + (man + woman - 1|cuplid),
                         data = acitelli_pair,
                         family = binomial,
                         na.action = na.omit)

apim_bin_di_two <- glmer(simhob_bin_A ~ gender_A + other_pos_A:gender_A + other_pos_P:ge
```

```
                          + (1|cuplid),
                          data = acitelli_pair,
                          family = binomial,
                          na.action = na.omit)

apim_bin_di_two <- glmer(simhob_bin_A ~ gender_A + other_pos_A:gender_A + other_pos_P:ge
                          + (man + woman - 1|cuplid),
                          data = acitelli_pair,
                          family = binomial,
                          na.action = na.omit,
                          nAGQ = 0) #Adaptive Gauss-Hermite Quadrature

summary(apim_bin_di_two)
```

```
## Generalized linear mixed model fit by maximum likelihood (Adaptive
##   Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
##  Family: binomial  ( logit )
## Formula:
## simhob_bin_A ~ gender_A + other_pos_A:gender_A + other_pos_P:gender_A -
##     1 + (man + woman - 1 | cuplid)
##    Data: acitelli_pair
##
##      AIC      BIC   logLik deviance df.resid
##    330.4    363.6   -156.2    312.4      287
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -0.97710 -0.52321 -0.39856  0.00841  1.90671
##
## Random effects:
##  Groups Name  Variance Std.Dev. Corr
##  cuplid man   1.257    1.121
##         woman 1.038    1.019    1.00
## Number of obs: 296, groups:  cuplid, 148
##
## Fixed effects:
##                           Estimate Std. Error z value Pr(>|z|)
## gender_Ahus                -7.1637     2.7924  -2.566   0.0103 *
## gender_Awife               -6.0917     2.4851  -2.451   0.0142 *
## gender_Ahus:other_pos_A     0.4259     0.5214   0.817   0.4141
## gender_Awife:other_pos_A    1.0173     0.4539   2.241   0.0250 *
## gender_Ahus:other_pos_P     0.9160     0.5003   1.831   0.0671 .
## gender_Awife:other_pos_P    0.1722     0.4655   0.370   0.7114
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             gndr_Ah gndr_Aw gndr_Ah:__A gndr_Aw:__A gndr_Ah:__P
## gender_Awif  0.153
## gndr_Ah:__A -0.641  -0.103
## gndr_Aw:__A -0.087  -0.611  -0.037
## gndr_Ah:__P -0.605  -0.090  -0.218       0.153
## gndr_Aw:__P -0.104  -0.629   0.164      -0.226      -0.036
```

Log-Linear Multilevel Modeling (Count variables)

Indistinguishable Dyads

```
apim_poi <- glmer(cigarettes_A ~ other_pos_A + other_pos_P
                  + (1|cuplid),
                  data = acitelli_pair,
                  family = poisson,
                  na.action = na.omit)

summary(apim_poi)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: poisson  ( log )
## Formula: cigarettes_A ~ other_pos_A + other_pos_P + (1 | cuplid)
##    Data: acitelli_pair
##
##      AIC      BIC   logLik deviance df.resid
##    820.9    835.7   -406.5    812.9      292
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.20041 -0.88056 -0.03589  0.47286  2.56546
##
## Random effects:
##  Groups Name        Variance Std.Dev.
##  cuplid (Intercept) 0.1721   0.4149
## Number of obs: 296, groups:  cuplid, 148
##
## Fixed effects:
##             Estimate Std. Error z value Pr(>|z|)
```

```
## (Intercept) -0.57749    0.70463  -0.820   0.4125
## other_pos_A  0.21754    0.12179   1.786   0.0741 .
## other_pos_P -0.06686    0.11803  -0.566   0.5711
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) oth__A
## other_pos_A -0.695
## other_pos_P -0.662 -0.069
## convergence code: 0
## Model failed to converge with max|grad| = 0.00263168 (tol = 0.001, component 1)
```

Distinguishable Dyads

Interaction approach.

```
apim_poi_di <- glmer(cigarettes_A ~ other_pos_A + other_pos_P + genderE_A
                     + other_pos_A*genderE_A + other_pos_P*genderE_A
                     + (man + woman - 1|cuplid),
                     data = acitelli_pair,
                     family = poisson,
                     na.action = na.omit)

summary(apim_poi_di)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: poisson  ( log )
## Formula:
## cigarettes_A ~ other_pos_A + other_pos_P + genderE_A + other_pos_A *
##     genderE_A + other_pos_P * genderE_A + (man + woman - 1 |      cuplid)
##    Data: acitelli_pair
##
##      AIC      BIC   logLik deviance df.resid
##    830.7    863.9   -406.4    812.7      287
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.18651 -0.88308 -0.03542  0.47722  2.47552
##
## Random effects:
##  Groups Name  Variance Std.Dev. Corr
##  cuplid man   0.1879   0.4334
```

```
##         woman 0.1559   0.3948   1.00
## Number of obs: 296, groups:  cuplid, 148
##
## Fixed effects:
##                       Estimate Std. Error z value Pr(>|z|)
## (Intercept)           -0.55052    0.70862  -0.777    0.437
## other_pos_A            0.21480    0.12269   1.751    0.080 .
## other_pos_P           -0.07016    0.11890  -0.590    0.555
## genderE_A             -0.02305    0.59232  -0.039    0.969
## other_pos_A:genderE_A -0.03722    0.12758  -0.292    0.770
## other_pos_P:genderE_A  0.04151    0.12386   0.335    0.738
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) oth__A oth__P gndE_A o__A:E
## other_pos_A -0.694
## other_pos_P -0.660 -0.073
## genderE_A    0.014 -0.086  0.070
## othr__A:E_A -0.093  0.107  0.016 -0.567
## othr__P:E_A  0.081 -0.017 -0.093 -0.519 -0.404
## convergence code: 0
## Model failed to converge with max|grad| = 0.011638 (tol = 0.001, component 1)
```

Two-intercept model.

```
apim_poi_di_two <- glmer(cigarettes_A ~ gender_A + other_pos_A:gender_A + other_pos_P:ge
                         + (man + woman - 1|cuplid),
                         data = acitelli_pair,
                         family = poisson,
                         na.action = na.omit)

summary(apim_poi_di_two)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: poisson  ( log )
## Formula:
## cigarettes_A ~ gender_A + other_pos_A:gender_A + other_pos_P:gender_A -
##     1 + (man + woman - 1 | cuplid)
##    Data: acitelli_pair
##
##      AIC      BIC   logLik deviance df.resid
##    830.7    864.0   -406.4    812.7      287
##
## Scaled residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -1.18560 -0.88295 -0.03557  0.47559  2.47507
##
## Random effects:
##  Groups Name  Variance Std.Dev. Corr
##  cuplid man   0.188    0.4336
##         woman 0.156    0.3950   1.00
## Number of obs: 296, groups:  cuplid, 148
##
## Fixed effects:
##                           Estimate Std. Error z value Pr(>|z|)
## gender_Ahus               -0.55598    0.92961  -0.598    0.550
## gender_Awife              -0.53193    0.91742  -0.580    0.562
## gender_Ahus:other_pos_A    0.17330    0.18620   0.931    0.352
## gender_Awife:other_pos_A   0.25334    0.16727   1.514    0.130
## gender_Ahus:other_pos_P   -0.02845    0.16352  -0.174    0.862
## gender_Awife:other_pos_P -0.11196    0.17954  -0.624    0.533
##
## Correlation of Fixed Effects:
##              gndr_Ah gndr_Aw gndr_Ah:__A gndr_Aw:__A gndr_Ah:__P
## gender_Awif   0.178
## gndr_Ah:__A -0.680  -0.116
## gndr_Aw:__A -0.098  -0.577  -0.039
## gndr_Ah:__P -0.537  -0.103  -0.245       0.176
## gndr_Aw:__P -0.119  -0.642   0.174      -0.247      -0.041
## convergence code: 0
## Model failed to converge with max|grad| = 0.0220828 (tol = 0.001, component 1)
```

Generalized Estimating Equations (GEE)

Indistinguishable Dyads

```
#install.packages("gee")
library(gee)

apim_gee <- gee(simhob_bin_A ~ other_pos_A + other_pos_P,
                id = cuplid,
                data = acitelli_pair,
                na.action = na.omit,
                family = binomial,
                corstr = "unstructured")
```

```
## (Intercept) other_pos_A other_pos_P
```

```
##  -6.2582893   0.6956734   0.5017679
```

```
summary(apim_gee)
```

```
##
##  GEE:  GENERALIZED LINEAR MODELS FOR DEPENDENT DATA
##  gee S-function, version 4.13 modified 98/01/27 (1998)
##
## Model:
##  Link:                      Logit
##  Variance to Mean Relation: Binomial
##  Correlation Structure:     Unstructured
##
## Call:
## gee(formula = simhob_bin_A ~ other_pos_A + other_pos_P, id = cuplid,
##     data = acitelli_pair, na.action = na.omit, family = binomial,
##     corstr = "unstructured")
##
## Summary of Residuals:
##         Min          1Q      Median          3Q         Max
## -0.43310561 -0.27624377 -0.19297150  0.07522507  0.86606888
##
##
## Coefficients:
##               Estimate Naive S.E.   Naive z Robust S.E.  Robust z
## (Intercept) -6.2729871  1.8140043 -3.458088   1.7415077 -3.602044
## other_pos_A  0.6982148  0.2901570  2.406334   0.2851282  2.448775
## other_pos_P  0.5025443  0.2840654  1.769115   0.2605414  1.928846
##
## Estimated Scale Parameter:  0.9978716
## Number of Iterations:  2
##
## Working Correlation
##           [,1]      [,2]
## [1,] 1.0000000 0.2703261
## [2,] 0.2703261 1.0000000
```