

Section 3 - covariates

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Does including Substance usage as additional Covariates show a similar story? is there a significant difference

There is the option of using standardized transformed and / or logarithmic transformed for the variables. In the following I opted for using the standardized Data, but avoiding an additional logarithmic transformation of the substance use data due to the fact that all models performed almost identically, though with a logarithmic transformation slightly better, but this would lead to a less intuitive interpretation. Furthermore, due to a flat optimization plane and different scales the two substance usage variables lie on, the standadisation of these variables alleviates these problems somewhat.

```
sm.nlme.robust2.1 <- lme(GPA ~ Avg_Drinks_current * Semester + Avg_Drinks_current * Avg_MJ_current + Avg_MJ_current * Semester, random = ~ 1 | BARCS_ID, data = data.file.long, na.action = na.omit)

sm.nlme.robust2.2 <- lme(GPA ~ Avg_Drinks_current * Semester + Avg_Drinks_current * Avg_MJ_current + Avg_MJ_current * Semester, random = ~ 1 | BARCS_ID, data = data.file.long, na.action = na.omit)

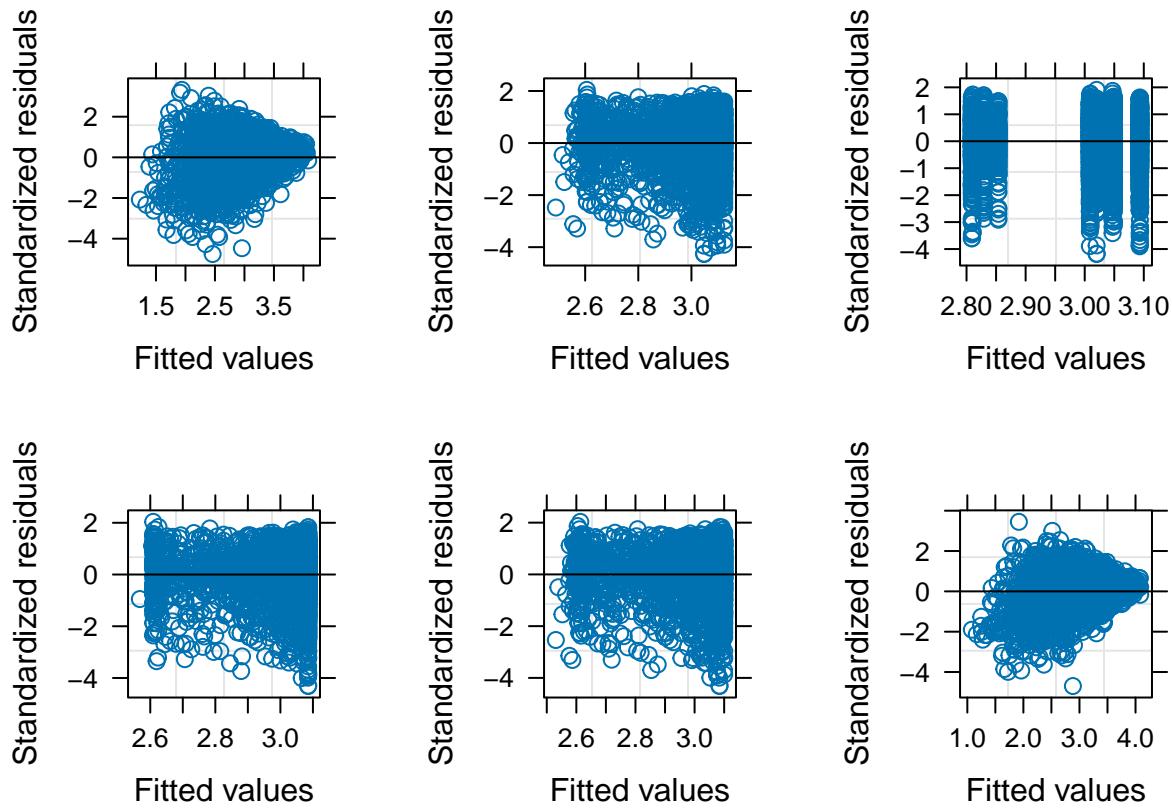
sm.nlme.ARMA11 <- lme(GPA ~ Cluster_current * Semester, random = ~ 1 | BARCS_ID, data = data.file.long, na.action = na.omit)

sm.nlme.noSemester <- lme(GPA ~ Avg_Drinks_current * Avg_MJ_current, random = ~ 1 | BARCS_ID, data = data.file.long, na.action = na.omit)

sm.nlme.noSemester.time <- lme(GPA ~ Avg_Drinks_current * Avg_MJ_current + Avg_Drinks_current*Time + Avg_MJ_current*Time, random = ~ 1 | BARCS_ID, data = data.file.long, na.action = na.omit)

sm.nlme.noSemester.timeRE <- lme(GPA ~ Avg_Drinks_current * Avg_MJ_current + Avg_Drinks_current*Time + Avg_MJ_current*Time, random = ~ 1 | BARCS_ID, data = data.file.long, na.action = na.omit, REML = TRUE)

cowplot::plot_grid(plot(sm.nlme.robust2.1), plot(sm.nlme.robust2.2), plot(sm.nlme.ARMA11), plot(sm.nlme.noSemester), plot(sm.nlme.noSemester.time), plot(sm.nlme.noSemester.timeRE))
```



```

## Linear mixed-effects model fit by REML
## Data: data.file.long
##      AIC      BIC    logLik
## 6564.343 6657.941 -3267.171
##
## Random effects:
##   Formula: ~1 | BARCS_ID
##             (Intercept) Residual
## StdDev:  0.5300164 0.4313632
##
## Fixed effects: GPA ~ Avg_Drinks_current * Semester + Avg_Drinks_current * Avg_MJ_current +
##                 Value Std.Error DF t-value p-value
##   (Intercept) 3.0953777 0.023477304 2650 131.84554 0.0000
##   Avg_Drinks_current -0.0022323 0.000580808 2650 -3.84336 0.0001
##   Semester2 -0.0464465 0.021954235 2650 -2.11560 0.0345
##   Semester3 -0.0110898 0.024051076 2650 -0.46110 0.6448
##   Semester4  0.0239989 0.024963406 2650  0.96136 0.3365
##   Avg_MJ_current -0.0192852 0.003488167 2650 -5.52874 0.0000
##   Avg_Drinks_current:Semester2 0.0004261 0.000651791 2650  0.65377 0.5133
##   Avg_Drinks_current:Semester3 0.0008217 0.000677718 2650  1.21246 0.2254
##   Avg_Drinks_current:Semester4 0.0005596 0.000718920 2650  0.77838 0.4364
##   Avg_Drinks_current:Avg_MJ_current 0.0000727 0.000032498 2650  2.23714 0.0254
##   Semester2:Avg_MJ_current 0.0017817 0.003555783 2650  0.50108 0.6164
##   Semester3:Avg_MJ_current 0.0016351 0.003809060 2650  0.42926 0.6678
##   Semester4:Avg_MJ_current -0.0008149 0.004129544 2650 -0.19734 0.8436
##
## Correlation:
##   (Intr) Avg_D_Smstr2 Smstr3 Smstr4 Av_MJ_
##   Avg_Drinks_current -0.401

```

```

## Semester2          -0.463  0.230
## Semester3          -0.419  0.210  0.461
## Semester4          -0.413  0.224  0.442  0.443
## Avg_MJ_current    -0.211 -0.134  0.062  0.030  0.015
## Avg_Drinks_current:Semester2   0.178 -0.481 -0.429 -0.198 -0.188  0.223
## Avg_Drinks_current:Semester3   0.184 -0.500 -0.211 -0.424 -0.204  0.264
## Avg_Drinks_current:Semester4   0.181 -0.504 -0.199 -0.203 -0.385  0.305
## Avg_Drinks_current:Avg_MJ_current  0.166 -0.386  0.009  0.045  0.053 -0.416
## Semester2:Avg_MJ_current     0.066  0.218 -0.115 -0.057 -0.053 -0.513
## Semester3:Avg_MJ_current     0.075  0.219 -0.057 -0.131 -0.054 -0.547
## Semester4:Avg_MJ_current     0.067  0.231 -0.053 -0.053 -0.134 -0.536
##                                         A_D_:S2 A_D_:S3 A_D_:S4 A_D_:A S2:A_M S3:A_M
## Avg_Drinks_current
## Semester2
## Semester3
## Semester4
## Avg_MJ_current
## Avg_Drinks_current:Semester2   0.466
## Avg_Drinks_current:Semester3   0.442  0.480
## Avg_Drinks_current:Semester4   0.442 -0.102 -0.154
## Avg_Drinks_current:Avg_MJ_current -0.045 -0.102 -0.154
## Semester2:Avg_MJ_current      -0.447 -0.206 -0.199  0.012
## Semester3:Avg_MJ_current      -0.205 -0.426 -0.214  0.030  0.482
## Semester4:Avg_MJ_current      -0.189 -0.204 -0.445  0.019  0.446  0.483
##
## Standardized Within-Group Residuals:
##      Min        Q1        Med        Q3        Max
## -4.7545632 -0.4194526  0.1076792  0.5410672  3.3205046
##
## Number of Observations: 3802
## Number of Groups: 1140
## Linear mixed-effects model fit by REML
## Data: data.file.long
##      AIC      BIC      logLik
## 6493.115 6599.193 -3229.558
##
## Random effects:
## Formula: ~1 | BARCS_ID
##           (Intercept) Residual
## StdDev: 0.0005764083 0.681948
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##      Phi1      Theta1
## 0.8627949 -0.3962917
## Fixed effects: GPA ~ Avg_Drinks_current * Semester + Avg_Drinks_current * Avg_MJ_current +
##                                         Value  Std.Error  DF  t-value p-value
## (Intercept)            3.0968642 0.023527380 2650 131.62809  0.0000
## Avg_Drinks_current    -0.0022374 0.000589083 2650 -3.79806  0.0001
## Semester2             -0.0491083 0.020609835 2650 -2.38276  0.0173
## Semester3             -0.0135507 0.024856848 2650 -0.54515  0.5857
## Semester4              0.0264856 0.027716910 2650  0.95558  0.3394

```

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## Avg_MJ_current          -0.0196831 0.003543619 2650 -5.55451 0.0000
## Avg_Drinks_current:Semester2 0.0004604 0.000613633 2650 0.75033 0.4531
## Avg_Drinks_current:Semester3 0.0009671 0.000685830 2650 1.41014 0.1586
## Avg_Drinks_current:Semester4 0.0006368 0.000762289 2650 0.83532 0.4036
## Avg_Drinks_current:Avg_MJ_current 0.0000718 0.000032427 2650 2.21537 0.0268
## Semester2:Avg_MJ_current 0.0020124 0.003345860 2650 0.60146 0.5476
## Semester3:Avg_MJ_current 0.0012128 0.003874523 2650 0.31303 0.7543
## Semester4:Avg_MJ_current -0.0011463 0.004420657 2650 -0.25931 0.7954
## Correlation:
##                                     (Intr) Avg_D_ Smstr2 Smstr3 Smstr4 Av_MJ_
## Avg_Drinks_current           -0.407
## Semester2                    -0.443  0.232
## Semester3                   -0.447  0.222  0.518
## Semester4                   -0.467  0.227  0.449  0.568
## Avg_MJ_current              -0.211 -0.142  0.056  0.035  0.036
## Avg_Drinks_current:Semester2 0.178 -0.479 -0.431 -0.214 -0.180  0.231
## Avg_Drinks_current:Semester3 0.198 -0.532 -0.234 -0.418 -0.229  0.278
## Avg_Drinks_current:Semester4 0.195 -0.522 -0.202 -0.236 -0.376  0.293
## Avg_Drinks_current:Avg_MJ_current 0.167 -0.373  0.012  0.046  0.045 -0.421
## Semester2:Avg_MJ_current    0.065  0.219 -0.113 -0.067 -0.060 -0.512
## Semester3:Avg_MJ_current    0.080  0.227 -0.063 -0.136 -0.085 -0.573
## Semester4:Avg_MJ_current    0.075  0.224 -0.056 -0.078 -0.149 -0.546
## A_D_:S2 A_D_:S3 A_D_:S4 A_D_:A S2:A_M S3:A_M
## Avg_Drinks_current
## Semester2
## Semester3
## Semester4
## Avg_MJ_current
## Avg_Drinks_current:Semester2
## Avg_Drinks_current:Semester3 0.509
## Avg_Drinks_current:Semester4 0.439  0.552
## Avg_Drinks_current:Avg_MJ_current -0.056 -0.110 -0.146
## Semester2:Avg_MJ_current     -0.449 -0.223 -0.193  0.022
## Semester3:Avg_MJ_current    -0.220 -0.418 -0.227  0.038  0.524
## Semester4:Avg_MJ_current    -0.183 -0.221 -0.423  0.025  0.444  0.568
##
## Standardized Within-Group Residuals:
##      Min        Q1        Med        Q3        Max
## -4.2638945 -0.5242594  0.1940455  0.7740628  2.0440889
##
## Number of Observations: 3802
## Number of Groups: 1140
## Linear mixed-effects model fit by REML
##   Data: data.file.long
##       AIC      BIC      logLik
##   6447.394 6547.236 -3207.697
##
## Random effects:
##   Formula: ~1 | BARCS_ID
##             (Intercept) Residual
##   StdDev: 0.001094668 0.6882237
##
## Correlation Structure: ARMA(1,1)

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## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##      Phi1      Theta1
## 0.8690401 -0.4041121
## Fixed effects: GPA ~ Cluster_current * Semester
##                                     Value Std.Error DF t-value
## (Intercept)           3.0930770 0.02809712 2651 110.08519
## Cluster_current2nd.cluster -0.0843512 0.03559830 2651 -2.36953
## Cluster_current3rd.cluster -0.2840857 0.04931153 2651 -5.76104
## Semester2            -0.0728936 0.02689653 2651 -2.71015
## Semester3            -0.0458509 0.03150097 2651 -1.45554
## Semester4             0.0003732 0.03576761 2651 0.01044
## Cluster_current2nd.cluster:Semester2 0.0736708 0.04043058 2651 1.82215
## Cluster_current3rd.cluster:Semester2 0.0929157 0.05089207 2651 1.82574
## Cluster_current2nd.cluster:Semester3 0.0865423 0.04624496 2651 1.87139
## Cluster_current3rd.cluster:Semester3 0.0907295 0.06217500 2651 1.45926
## Cluster_current2nd.cluster:Semester4 0.0847991 0.05225097 2651 1.62292
## Cluster_current3rd.cluster:Semester4 0.0010991 0.07057501 2651 0.01557
##                                     p-value
## (Intercept)          0.0000
## Cluster_current2nd.cluster 0.0179
## Cluster_current3rd.cluster 0.0000
## Semester2            0.0068
## Semester3             0.1456
## Semester4              0.9917
## Cluster_current2nd.cluster:Semester2 0.0685
## Cluster_current3rd.cluster:Semester2 0.0680
## Cluster_current2nd.cluster:Semester3 0.0614
## Cluster_current3rd.cluster:Semester3 0.1446
## Cluster_current2nd.cluster:Semester4 0.1047
## Cluster_current3rd.cluster:Semester4 0.9876
## Correlation:
##                                     (Intr) Cls_2. Cls_3. Smstr2 Smstr3 Smstr4
## Cluster_current2nd.cluster -0.634
## Cluster_current3rd.cluster -0.497  0.405
## Semester2                 -0.500  0.430  0.299
## Semester3                 -0.509  0.425  0.297  0.522
## Semester4                 -0.502  0.402  0.288  0.448  0.552
## Cluster_current2nd.cluster:Semester2 0.366 -0.591 -0.210 -0.703 -0.359 -0.308
## Cluster_current3rd.cluster:Semester2 0.272 -0.199 -0.591 -0.534 -0.276 -0.237
## Cluster_current2nd.cluster:Semester3 0.367 -0.596 -0.205 -0.370 -0.690 -0.368
## Cluster_current3rd.cluster:Semester3 0.267 -0.205 -0.562 -0.267 -0.508 -0.277
## Cluster_current2nd.cluster:Semester4 0.355 -0.570 -0.208 -0.318 -0.367 -0.688
## Cluster_current3rd.cluster:Semester4 0.258 -0.198 -0.541 -0.231 -0.279 -0.507
##                                     C_2.:S2 C_3.:S2 C_2.:S3 C_3.:S3 C_2.:S4
## Cluster_current2nd.cluster
## Cluster_current3rd.cluster
## Semester2
## Semester3
## Semester4
## Cluster_current2nd.cluster:Semester2 0.349
## Cluster_current3rd.cluster:Semester2 0.511  0.183
## Cluster_current2nd.cluster:Semester3 0.174  0.524  0.339

```

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## Cluster_current2nd.cluster:Semester4  0.438   0.156   0.520   0.181
## Cluster_current3rd.cluster:Semester4  0.152   0.454   0.186   0.538   0.344
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3       Max
## -4.1849446 -0.5142061  0.1875018  0.7715535  1.9075375
##
## Number of Observations: 3802
## Number of Groups: 1140

## Linear mixed-effects model fit by REML
## Data: data.file.long
##      AIC      BIC    logLik
## 6404.016 6453.953 -3194.008
##
## Random effects:
## Formula: ~1 | BARCS_ID
##             (Intercept) Residual
## StdDev: 0.0008872561 0.6831914
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##     Phi1     Theta1
## 0.8654627 -0.4013012
## Fixed effects: GPA ~ Avg_Drinks_current * Avg_MJ_current
##                               Value  Std.Error   DF   t-value p-value
## (Intercept)            3.0854537 0.019646715 2659 157.04680 0.0000
## Avg_Drinks_current     -0.0017764 0.000458965 2659 -3.87036 0.0001
## Avg_MJ_current         -0.0190705 0.002639929 2659 -7.22388 0.0000
## Avg_Drinks_current:Avg_MJ_current 0.0000764 0.000032016 2659   2.38717 0.0170
## Correlation:
##                               (Intr) Avg_D_ Av_MJ_
## Avg_Drinks_current     -0.386
## Avg_MJ_current          -0.278  0.119
## Avg_Drinks_current:Avg_MJ_current 0.233 -0.591 -0.525
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3       Max
## -4.3113105 -0.5192914  0.1835225  0.7682582  2.0359910
##
## Number of Observations: 3802
## Number of Groups: 1140

## Linear mixed-effects model fit by REML
## Data: data.file.long
##      AIC      BIC    logLik
## 6440.725 6509.38 -3209.362
##
## Random effects:
## Formula: ~1 | BARCS_ID
##             (Intercept) Residual
## StdDev: 0.0008990533 0.6824516
##
## Correlation Structure: ARMA(1,1)

```

```

## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##      Phi1      Theta1
## 0.8648189 -0.4011802
## Fixed effects: GPA ~ Avg_Drinks_current * Avg_MJ_current + Avg_Drinks_current *
##                                         Value Std.Error DF t-value p-value
## (Intercept)            3.0683715 0.028297500 2656 108.43260 0.0000
## Avg_Drinks_current    -0.0023011 0.000731411 2656 -3.14617 0.0017
## Avg_MJ_current         -0.0183701 0.004387132 2656 -4.18727 0.0000
## Time                  0.0079335 0.008992418 2656 0.88225 0.3777
## Avg_Drinks_current:Avg_MJ_current 0.0000703 0.000032428 2656 2.16683 0.0303
## Avg_Drinks_current:Time       0.0002353 0.000245947 2656 0.95661 0.3388
## Avg_MJ_current:Time        -0.0002263 0.001427435 2656 -0.15851 0.8741
## Correlation:
##                               (Intr) Avg_D_ Av_MJ_ Time   A_D_:A A_D_:T
## Avg_Drinks_current     -0.401
## Avg_MJ_current          -0.179 -0.260
## Time                   -0.720  0.314  0.077
## Avg_Drinks_current:Avg_MJ_current 0.120 -0.248 -0.345  0.052
## Avg_Drinks_current:Time      0.287 -0.778  0.386 -0.386 -0.152
## Avg_MJ_current:Time        0.117  0.329 -0.796 -0.148  0.030 -0.416
##
## Standardized Within-Group Residuals:
##      Min      Q1      Med      Q3      Max
## -4.3142032 -0.5220942  0.1841038  0.7678579  2.0316602
##
## Number of Observations: 3802
## Number of Groups: 1140
## Linear mixed-effects model fit by REML
## Data: data.file.long
##      AIC      BIC      logLik
## 6449.891 6518.547 -3213.946
##
## Random effects:
## Formula: ~1 + Time | BARCS_ID
## Structure: General positive-definite, Log-Cholesky parametrization
##             StdDev   Corr
## (Intercept) 0.6132209 (Intr)
## Time        0.1418704 -0.48
## Residual    0.3947151
##
## Fixed effects: GPA ~ Avg_Drinks_current * Avg_MJ_current + Avg_Drinks_current *
##                                         Value Std.Error DF t-value p-value
## (Intercept)            3.0674648 0.027795767 2656 110.35726 0.0000
## Avg_Drinks_current    -0.0023128 0.000726402 2656 -3.18390 0.0015
## Avg_MJ_current         -0.0185454 0.004349365 2656 -4.26394 0.0000
## Time                  0.0062204 0.009037449 2656 0.68829 0.4913
## Avg_Drinks_current:Avg_MJ_current 0.0000722 0.000032517 2656 2.22104 0.0264
## Avg_Drinks_current:Time       0.0002324 0.000246808 2656 0.94162 0.3465
## Avg_MJ_current:Time        -0.0000541 0.001433033 2656 -0.03775 0.9699
## Correlation:
##                               (Intr) Avg_D_ Av_MJ_ Time   A_D_:A A_D_:T
## Avg_Drinks_current     -0.402

```

```

## Avg_MJ_current           -0.178 -0.261
## Time                      -0.704  0.310  0.072
## Avg_Drinks_current:Avg_MJ_current  0.121 -0.252 -0.346  0.053
## Avg_Drinks_current:Time        0.287 -0.775  0.387 -0.386 -0.149
## Avg_MJ_current:Time         0.116  0.331 -0.792 -0.148  0.027 -0.416
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3       Max
## -4.69479017 -0.40259384  0.09553876  0.51131502  3.44726536
##
## Number of Observations: 3802
## Number of Groups: 1140
AIC_values.sm.r2 <- AIC(sm.nlme.robust2.1, sm.nlme.robust2.2, sm.nlme.ARMA11, sm.nlme.noSemester, sm.nlme.time)
## Warning in AIC.default(sm.nlme.robust2.1, sm.nlme.robust2.2, sm.nlme.ARMA11, :
## models are not all fitted to the same number of observations
BIC_values.sm.r2 <- BIC(sm.nlme.robust2.1, sm.nlme.robust2.2, sm.nlme.ARMA11, sm.nlme.noSemester, sm.nlme.time)
## Warning in BIC.default(sm.nlme.robust2.1, sm.nlme.robust2.2, sm.nlme.ARMA11, :
## models are not all fitted to the same number of observations
df_scores_sm.r2 <- data.frame(AIC_values.sm.r2, BIC_values.sm.r2)
df_scores_sm.r2

##          df      AIC df.1      BIC
## sm.nlme.robust2.1 15 6564.343 15 6657.941
## sm.nlme.robust2.2 17 6493.115 17 6599.193
## sm.nlme.ARMA11    16 6447.394 16 6547.236
## sm.nlme.noSemester 8 6404.016 8 6453.953
## sm.nlme.noSemester.time 11 6440.725 11 6509.380
## sm.nlme.noSemester.timeRE 11 6449.891 11 6518.547

```

no time / Semester > Time > Semester. Semester Pretty bad. The same holds for the full model.

```

library(mgcv)

## This is mgcv 1.9-1. For overview type 'help("mgcv-package")'.
sm.splines.ni <- gamm(
  GPA ~ s(Avg_Drinks_current, bs = "ps") + s(Avg_MJ_current, bs = "ps"),
  data = outlier.removed,
  na.action = na.exclude,
  correlation = corARMA(p = 1, q = 1, form = ~ Time | BARCS_ID)
)

# sm.splines.so <- sm.splines.1 <- gamm(
#   GPA ~ s(Avg_Drinks_current, bs = "ps")*s(Avg_MJ_current, bs = "ps"),
#   data = outlier.removed,
#   na.action = na.exclude,
#   correlation = corARMA(p = 1, q = 1, form = ~ Time | BARCS_ID)
# )

sm.splines.1 <- gamm(
  GPA ~ te(Avg_Drinks_current, Avg_MJ_current, bs = "ps"),
  random = list(BARCS_ID = ~ 1),
  data = outlier.removed,
)
```

```

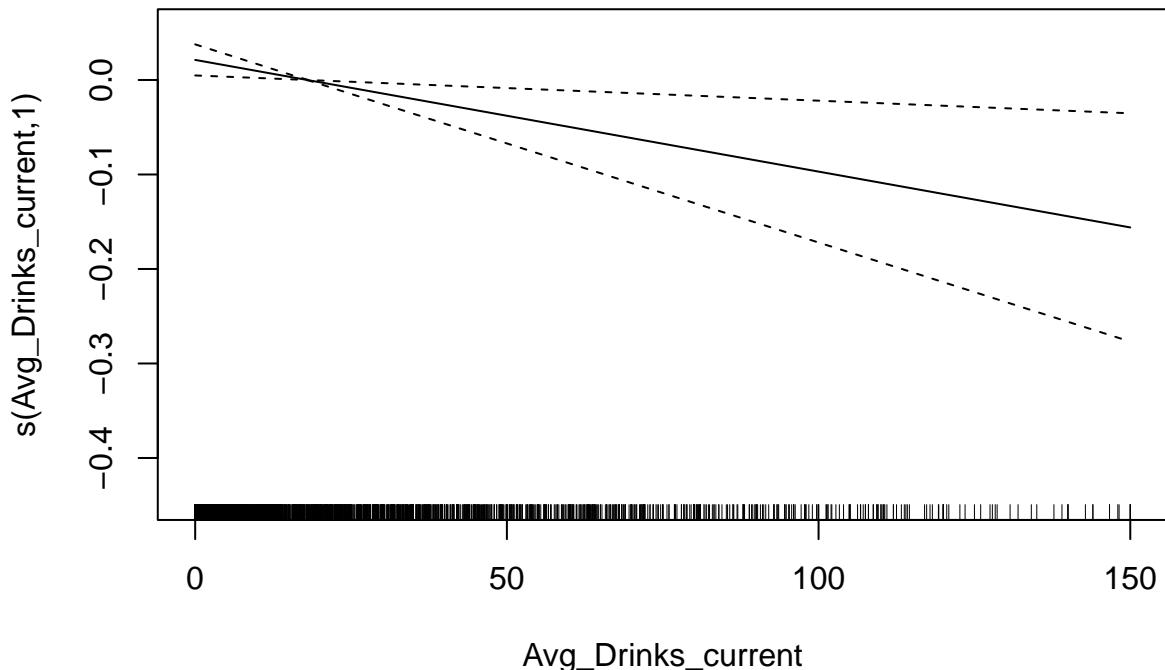
na.action = na.exclude,
correlation = corARMA(p = 1, q = 1, form = ~ Time | BARCS_ID)
)

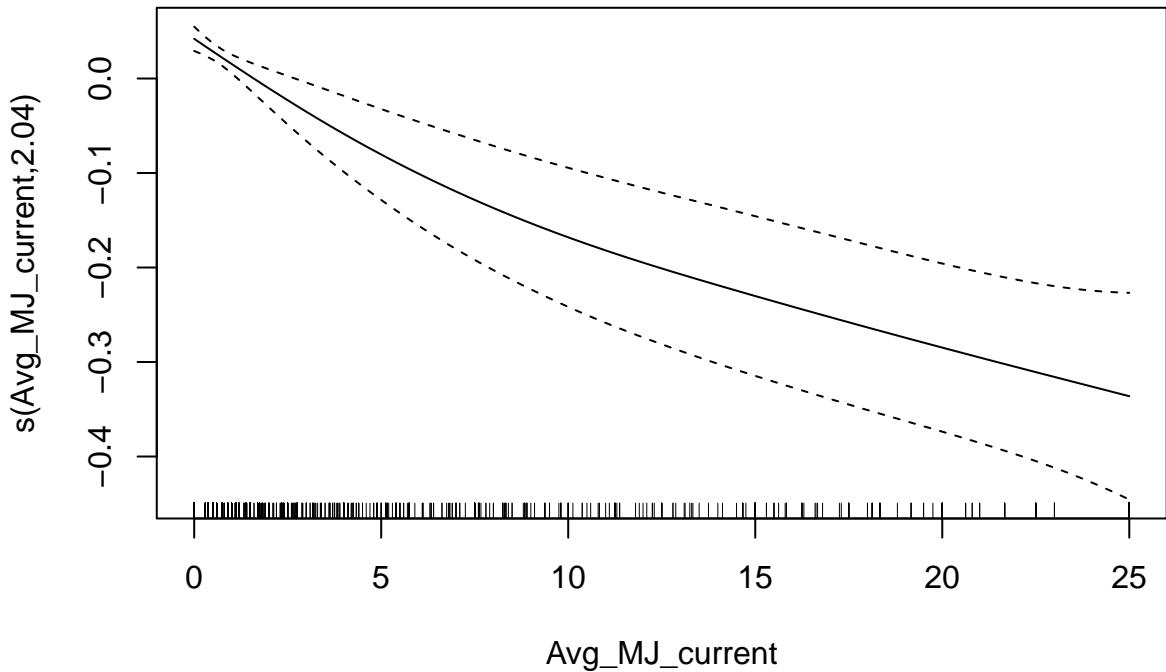
# sm.splines.2 <- gamm(
#   GPA ~ s(I(Avg_Drinks_current*I(4*Avg_MJ_current)), bs = "ps"),
#   random = list(BARCS_ID = ~ 1),
#   data = outlier.removed,
#   na.action = na.exclude,
#   correlation = corARMA(p = 1, q = 1, form = ~ Time / BARCS_ID)
# )

sm.splines.mix <- gamm(
  GPA ~ Avg_Drinks_current + s(Avg_MJ_current, bs = "ps"),
  data = outlier.removed,
  na.action = na.exclude,
  correlation = corARMA(p = 1, q = 1, form = ~ Time | BARCS_ID)
)

plot.gam(sm.splines.ni$gam, all.terms = TRUE)

```





```

summary(sm.splines.ni$gam)

## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length

## Warning in w * (as.numeric(object$y) - object$fitted.values): longer object
## length is not a multiple of shorter object length

##
## Family: gaussian
## Link function: identity
##
## Formula:
## GPA ~ s(Avg_Drinks_current, bs = "ps") + s(Avg_MJ_current, bs = "ps")
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 3.01907   0.01732   174.3 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                      edf Ref.df      F p-value
## s(Avg_Drinks_current) 1.000 1.000  6.677  0.0098 **
## s(Avg_MJ_current)     2.038 2.038 24.135 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =      NA
## Scale est. = 0.46494  n = 3756
summary(sm.splines.ni$lme)

## Linear mixed-effects model fit by maximum likelihood

```

```

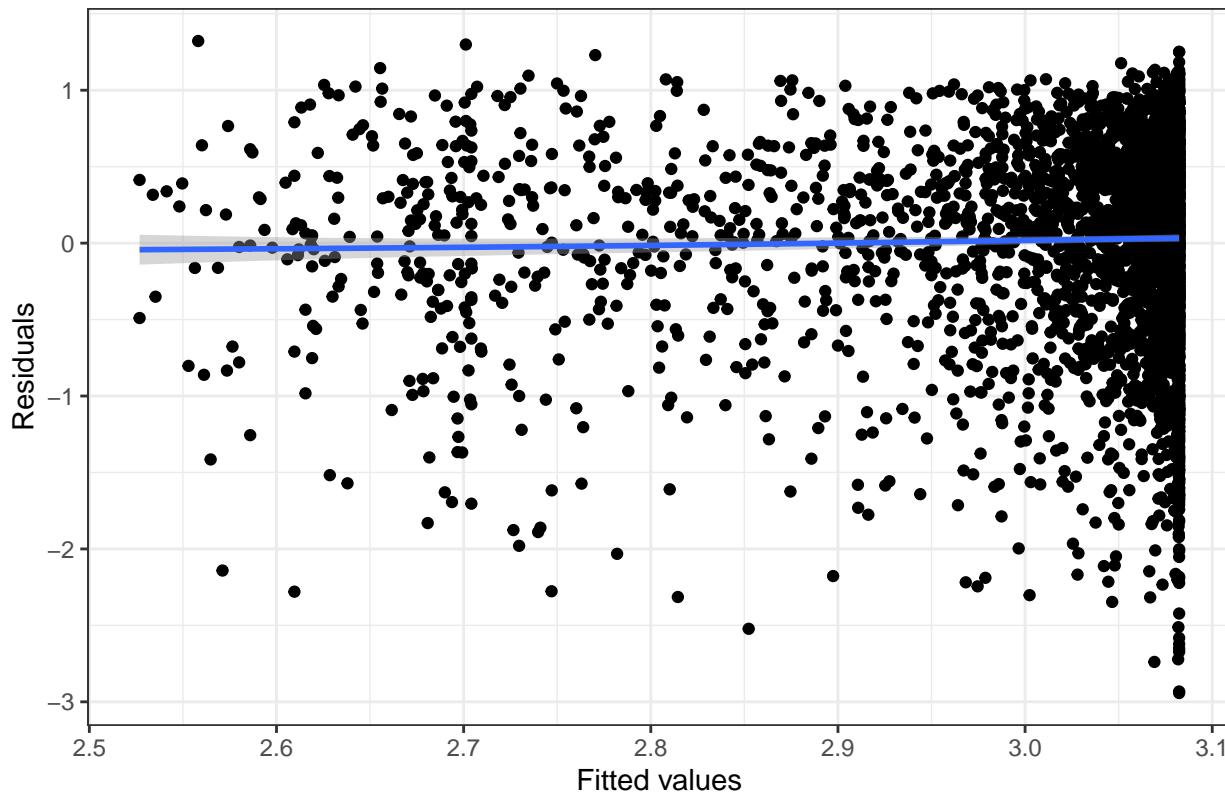
##   Data: strip.offset(mf)
##      AIC      BIC    logLik
## 6249.088 6298.937 -3116.544
##
## Random effects:
##   Formula: ~Xr - 1 | g
##   Structure: pdIdnot
##           Xr1          Xr2          Xr3          Xr4          Xr5
## StdDev: 9.436301e-06 9.436301e-06 9.436301e-06 9.436301e-06 9.436301e-06
##           Xr6          Xr7          Xr8
## StdDev: 9.436301e-06 9.436301e-06 9.436301e-06
##
##   Formula: ~Xr.0 - 1 | g.0 %in% g
##   Structure: pdIdnot
##           Xr.01         Xr.02         Xr.03         Xr.04         Xr.05         Xr.06
## StdDev: 0.00743553 0.00743553 0.00743553 0.00743553 0.00743553 0.00743553
##           Xr.07         Xr.08   Residual
## StdDev: 0.00743553 0.00743553 0.6818656
##
## Correlation Structure: ARMA(1,1)
##   Formula: ~Time | g/g.0/BARCS_ID
##   Parameter estimate(s):
##     Phi1     Theta1
## 0.8635817 -0.3919125
## Fixed effects: y ~ X - 1
##                 Value Std.Error DF t-value p-value
## X(Intercept) 3.0190688 0.01732617 3753 174.24905 0.0000
## Xs(Avg_Drinks_current)Fx1 -0.3139445 0.12152821 3753 -2.58331 0.0098
## Xs(Avg_MJ_current)Fx1 0.7220589 0.10581364 3753 6.82387 0.0000
## Correlation:
##           X(Int) X(A_D_
## Xs(Avg_Drinks_current)Fx1 -0.014
## Xs(Avg_MJ_current)Fx1 0.018 0.265
##
## Standardized Within-Group Residuals:
##       Min      Q1      Med      Q3      Max
## -4.3150993 -0.5171132 0.1862897 0.7689271 1.9385551
##
## Number of Observations: 3756
## Number of Groups:
##   g g.0 %in% g
## 1 1

fitted.ni <- fitted(sm.splines.ni$lm)
resid.ni <- resid(sm.splines.ni$lm)
df.ni <- data.frame(fitted.ni, resid.ni)
ggplot.ni <- ggplot(df.ni, aes(x = fitted.ni, y = resid.ni)) +
  geom_point() +
  geom_smooth() +
  labs(title = "Residuals vs Fitted values NI", x = "Fitted values", y = "Residuals") +
  theme_bw()
ggplot.ni

## `geom_smooth()` using method = 'gam' and formula = 'y ~ s(x, bs = "cs")'

```

Residuals vs Fitted values NI



```
# plot(fitted(sm.splines.ni$lme), resid(sm.splines.ni$lme))
# abline(h = 0, col="red")

summary(sm.splines.1$gam)

## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length
## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length

##
## Family: gaussian
## Link function: identity
##
## Formula:
## GPA ~ te(Avg_Drinks_current, Avg_MJ_current, bs = "ps")
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 3.01911   0.01732 174.3 <2e-16 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                               edf Ref.df      F p-value
## te(Avg_Drinks_current,Avg_MJ_current) 4.336 4.336 18.18 <2e-16 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```

## 
## R-sq.(adj) =      NA
##   Scale est. = 0.46212    n = 3756
summary(sm.splines.1$lme)

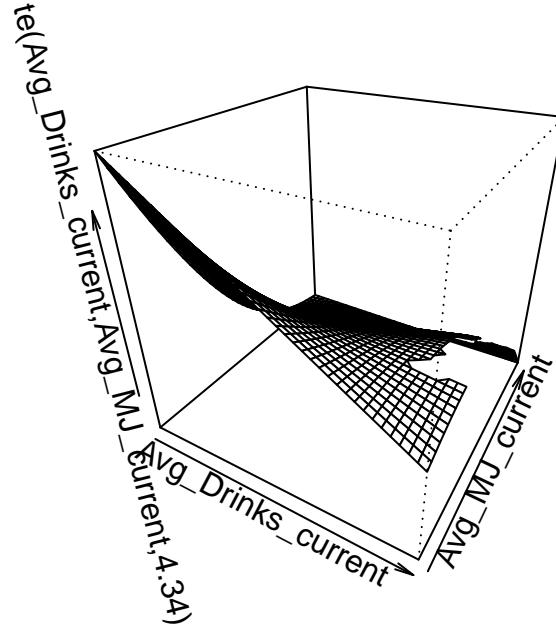
## Linear mixed-effects model fit by maximum likelihood
## Data: strip.offset(mf)
##       AIC      BIC    logLik
## 6247.954 6310.265 -3113.977
##
## Random effects:
## Formula: ~Xr - 1 | g
## Structure: pdTens
##             Xr1     Xr2     Xr3     Xr4     Xr5     Xr6     Xr7     Xr8
## StdDev: 5837.106 5827.864 2167.3 5833.703 5837.341 2762.272 1116.085 49.9166
##             Xr9     Xr10    Xr11    Xr12    Xr13    Xr14    Xr15    Xr16
## StdDev: 4919.063 2124.723 2115.966 422.1304 2126.288 2110.963 18.18243 245.9019
##             Xr17    Xr18    Xr19    Xr20    Xr21
## StdDev: 358.2707 366.6508 309.9095 3.135325 155.5529
##
## Formula: ~1 | BARCS_ID %in% g
##           (Intercept) Residual
## StdDev: 0.0509454 0.6797904
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | g/BARCS_ID
## Parameter estimate(s):
##       Phi1     Theta1
## 0.8625020 -0.3908868
## Fixed effects: y ~ X - 1
##                               Value Std.Error DF t-value
## X(Intercept)            3.0191136 0.0173297 2615 174.21619
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1 -0.1270495 0.1367807 2615 -0.92886
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2 -1.0128457 0.2129054 2615 -4.75726
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3  0.6948955 0.1189185 2615  5.84346
##                                         p-value
## X(Intercept)                      0.000
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1  0.353
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2  0.000
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3  0.000
## Correlation:
##           X(Int) X(A_D_,A_MJ_)F1
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1  0.003
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2 -0.021 -0.258
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3  0.012  0.022
##           X(A_D_,A_MJ_)F2
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3  0.123
##
## Standardized Within-Group Residuals:
##       Min      Q1      Med      Q3      Max
## -4.3265892 -0.5175710  0.1891080  0.7683537  1.9635257
##

```

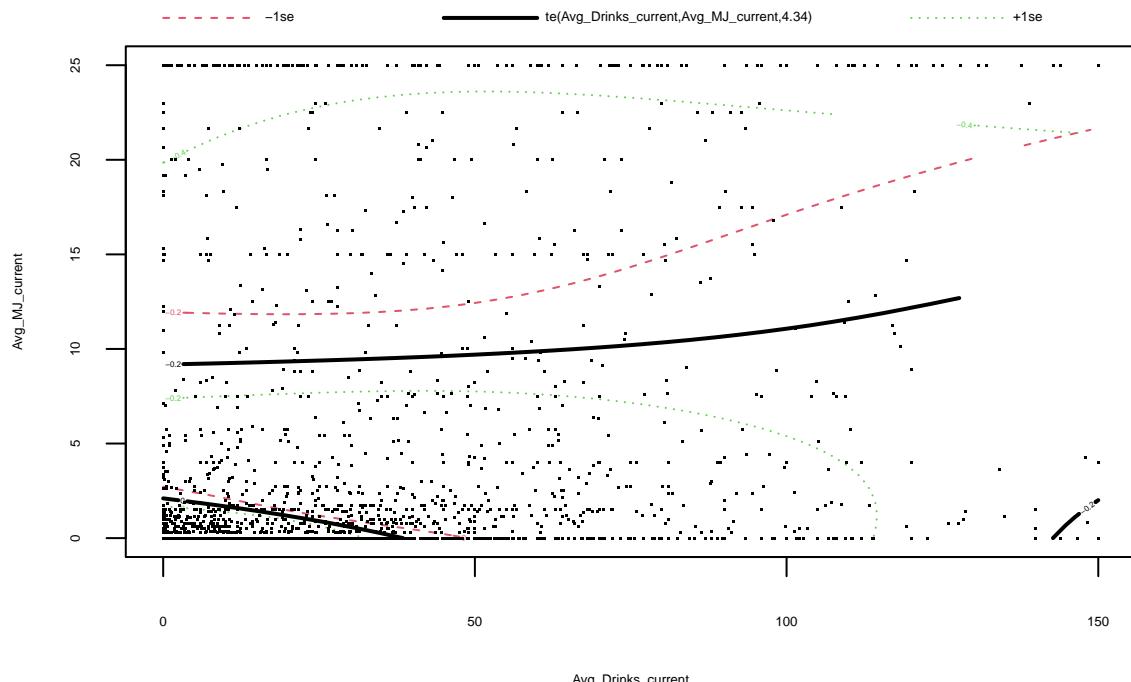
```

## Number of Observations: 3756
## Number of Groups:
##      g BARCS_ID %in% g
##      1           1138
plot(sm.splines.1$gam, pages = 1, scheme = 1, shade = TRUE, shade.col = "lightblue")

```

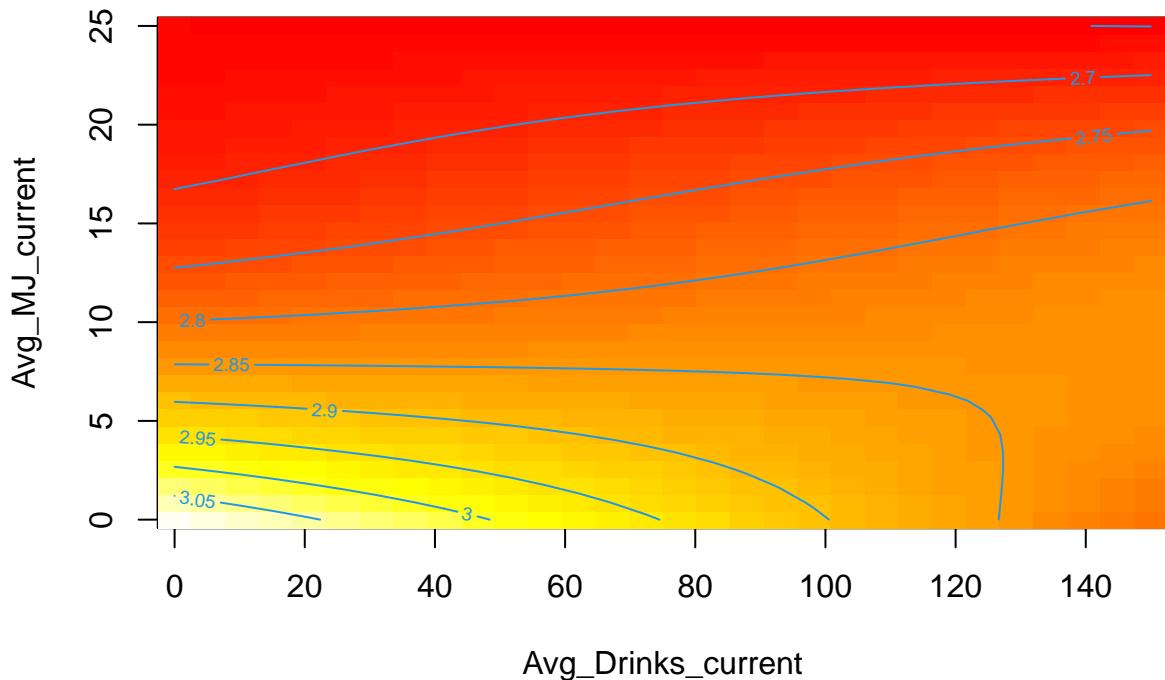


```
plot.gam(sm.splines.1$gam, all.terms = TRUE)
```



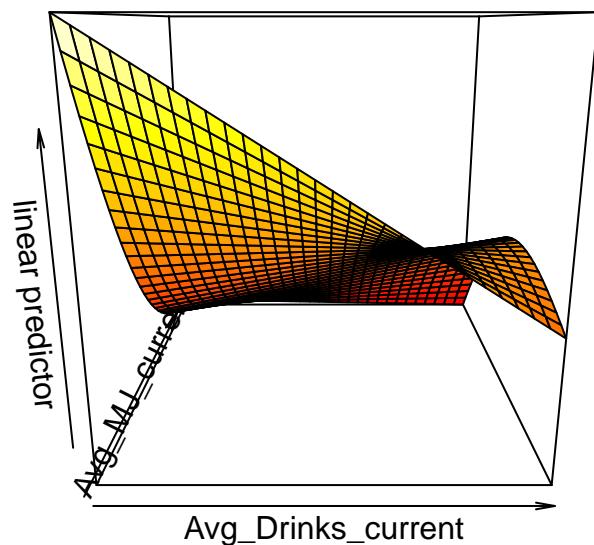
```
vis.gam(sm.splines.1$gam, view = c("Avg_Drinks_current", "Avg_MJ_current"), plot.type = "contour")
```

linear predictor



Avg_Drinks_current

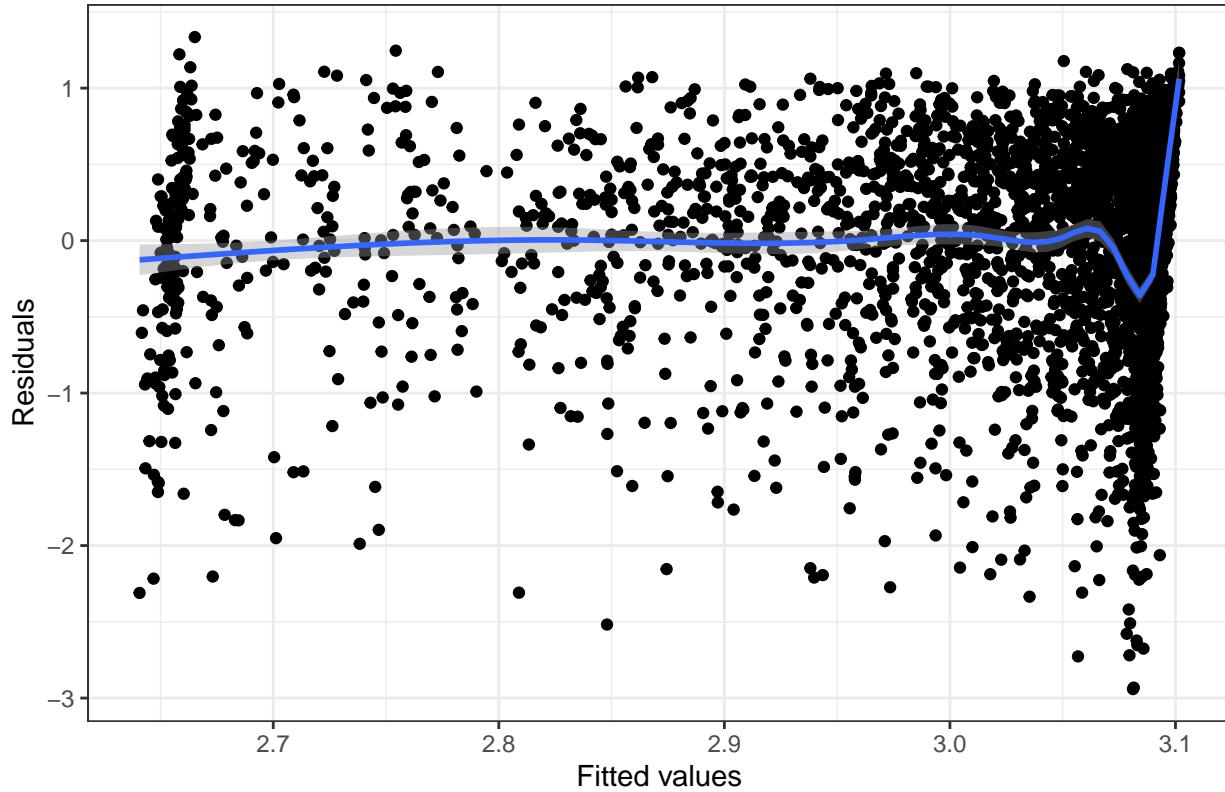
```
vis.gam(sm.splines.1$gam, view = c("Avg_Drinks_current", "Avg_MJ_current"), plot.type = "persp")
```



```
fitted.1 <- fitted(sm.splines.1$lme)
resid.1 <- resid(sm.splines.1$lme)
df.1 <- data.frame(fitted.1, resid.1)
ggplot.1 <- ggplot(df.1, aes(x = fitted.1, y = resid.1)) +
  geom_point() +
  geom_smooth() +
  labs(title = "Residuals vs Fitted values Spline 1", x = "Fitted values", y = "Residuals") +
  theme_bw()
ggplot.1
```

```
## `geom_smooth()` using method = 'gam' and formula = 'y ~ s(x, bs = "cs")'
```

Residuals vs Fitted values Spline 1



```
# summary(sm.splines.2$gam)
# summary(sm.splines.2$lme)
# plot.gam(sm.splines.2$gam, all.terms = TRUE)
#
# fitted.2 <- fitted(sm.splines.2$lme)
# resid.2 <- resid(sm.splines.2$lme)
# df.2 <- data.frame(fitted.2, resid.2)
# ggplot.2 <- ggplot(df.2, aes(x = fitted.2, y = resid.2)) +
#   geom_point() +
#   geom_smooth() +
#   labs(title = "Residuals vs Fitted values Spline 2", x = "Fitted values", y = "Residuals") +
#   theme_bw()
# ggplot.2

summary(sm.splines.mix$gam)

## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length
## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length

##
## Family: gaussian
## Link function: identity
##
## Formula:
```

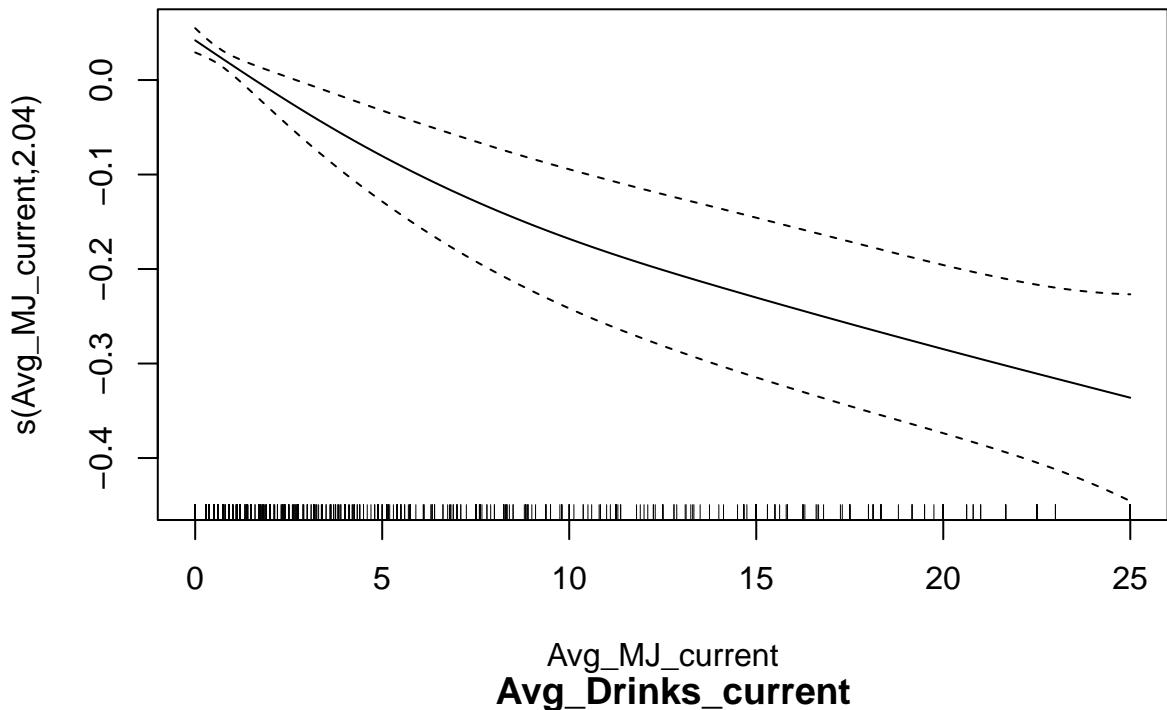
```

## GPA ~ Avg_Drinks_current + s(Avg_MJ_current, bs = "ps")
##
## Parametric coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)            3.0403133  0.0192828 157.669 < 2e-16 ***
## Avg_Drinks_current -0.0011819  0.0004575  -2.584  0.00982 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                  edf Ref.df      F p-value
## s(Avg_MJ_current) 2.039  2.039 24.12 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =     NA
## Scale est. = 0.46494   n = 3756
summary(sm.splines.mix$lme)

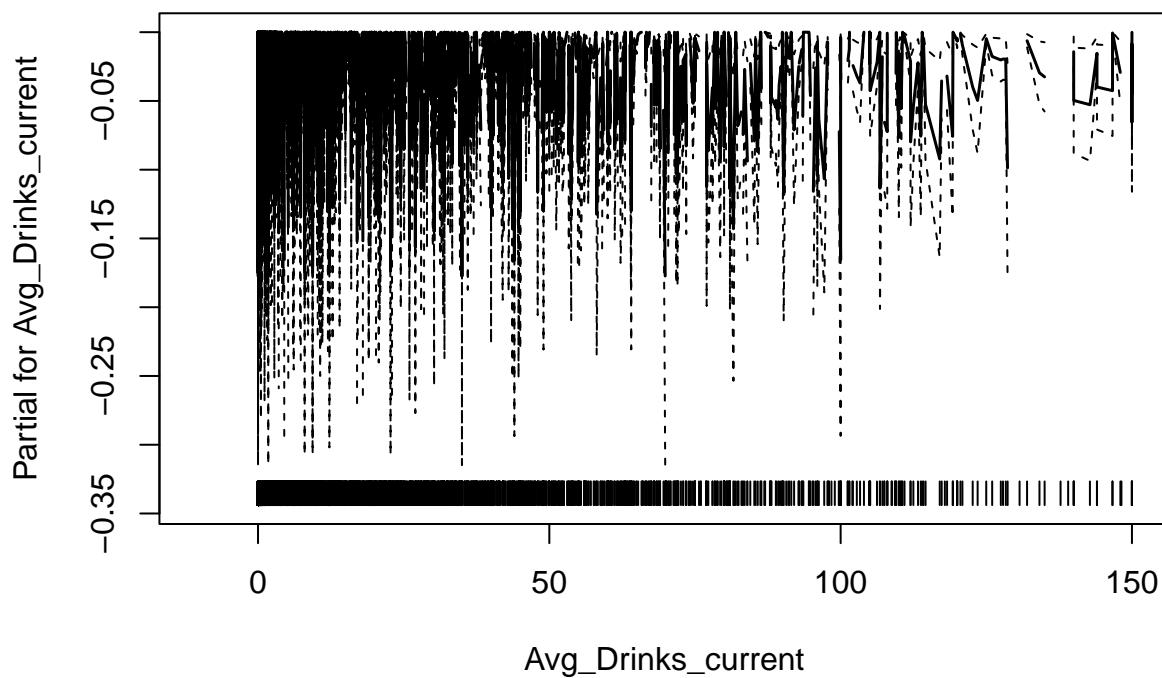
## Linear mixed-effects model fit by maximum likelihood
## Data: strip.offset(mf)
##      AIC      BIC    logLik
## 6247.088 6290.706 -3116.544
##
## Random effects:
## Formula: ~Xr - 1 | g
## Structure: pdIdnot
##             Xr1        Xr2        Xr3        Xr4        Xr5        Xr6
## StdDev: 0.00743824 0.00743824 0.00743824 0.00743824 0.00743824 0.00743824
##             Xr7        Xr8  Residual
## StdDev: 0.00743824 0.00743824 0.6818654
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | g/BARCS_ID
## Parameter estimate(s):
##      Phi1      Theta1
## 0.8635814 -0.3919120
## Fixed effects: y ~ X - 1
##                 Value Std.Error DF  t-value p-value
## X(Intercept) 3.0403133 0.01928540 3753 157.64847 0.0000
## XAvg_Drinks_current -0.0011819 0.00045753 3753 -2.58324 0.0098
## Xs(Avg_MJ_current)Fx1 0.7220631 0.10581438 3753  6.82387 0.0000
## Correlation:
##             X(Int) XAv_D_
## XAvg_Drinks_current -0.439
## Xs(Avg_MJ_current)Fx1 -0.097  0.265
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3       Max
## -4.3151025 -0.5171153  0.1862971  0.7689363  1.9385487
##
## Number of Observations: 3756
## Number of Groups: 1

```

```
plot.gam(sm.splines.mix$gam, all.terms = TRUE)
```



Avg_MJ_current
Avg_Drinks_current



```
fitted.mix <- fitted(sm.splines.mix$lme)
resid.mix <- resid(sm.splines.mix$lme)
df.mix <- data.frame(fitted.mix, resid.mix)
ggplot.mix <- ggplot(df.mix, aes(x = fitted.mix, y = resid.mix)) +
  geom_point() +
  geom_smooth()
```

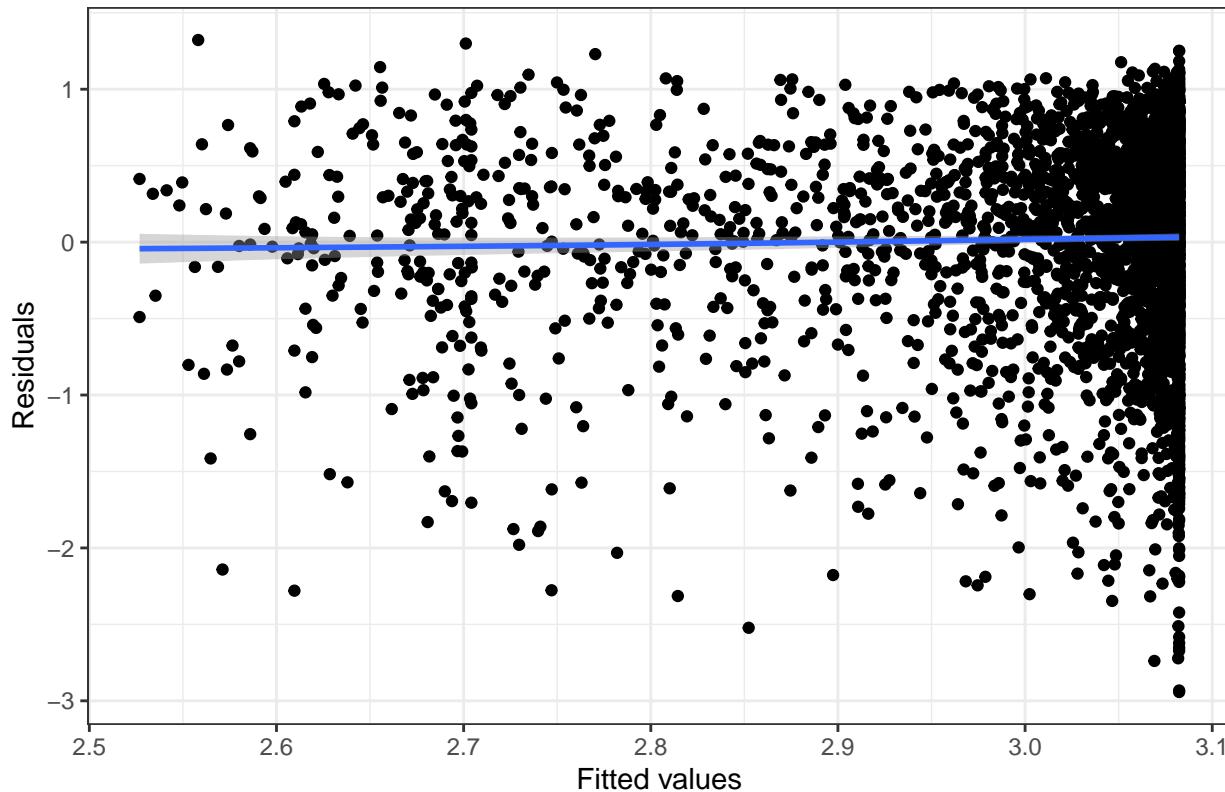
```

  labs(title = "Residuals vs Fitted values Spline mix", x = "Fitted values", y = "Residuals") +
  theme_bw()
ggplot.mix

```

```
## `geom_smooth()` using method = 'gam' and formula = 'y ~ s(x, bs = "cs")'
```

Residuals vs Fitted values Spline mix



```
AIC(sm.splines.ni, sm.splines.1, sm.splines.mix)
```

```

##          df      AIC
## sm.splines.ni  8 6249.088
## sm.splines.1 10 6247.954
## sm.splines.mix 7 6247.088

```

```
sm.outlier.barebones <- lme(GPA ~ Avg_Drinks_current + Avg_MJ_current, random = ~ 1 | BARCS_ID, data = outlier.re)
```

```
# sm.outlier<- lme(GPA ~ Avg_Drinks_current * Avg_MJ_current, random = ~ 1 | BARCS_ID, data = outlier.re)
##not invertible anymore for non standardised data
```

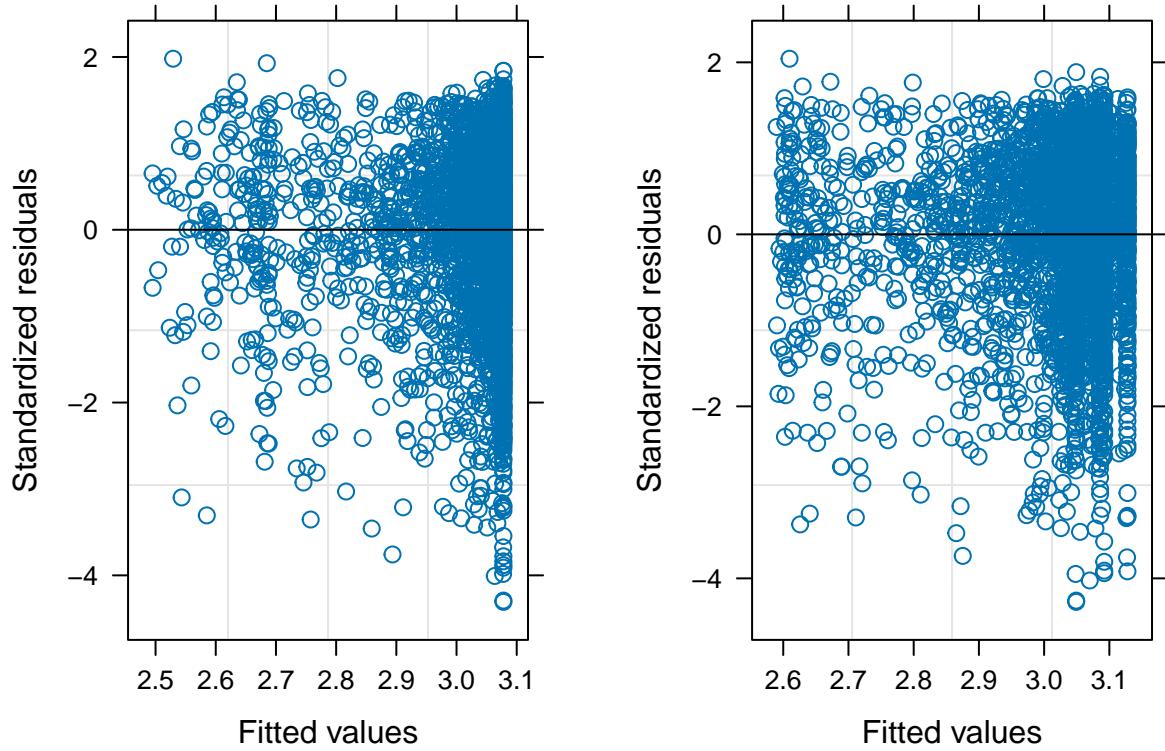
```
sm.outlier.semester <- lme(GPA ~ Avg_Drinks_current * Semester + Avg_Drinks_current * Avg_MJ_current + Semester * Avg_MJ_current)
```

```
fm.outlier.barebones <- lme(GPA ~ Avg_Drinks_current + Avg_MJ_current + Sex + Age1stround + SATMath + SATVerbal + SATComposite)
```

```
fm.outlier<- lme(GPA ~ Avg_Drinks_current * Avg_MJ_current + Sex + Age1stround + SATMath + SATVerbal + SATComposite)
```

```
fm.outlier.semester <- lme(GPA ~ Avg_Drinks_current * Semester + Avg_Drinks_current * Avg_MJ_current + Semester * Avg_MJ_current)
```

```
cowplot::plot_grid(plot(sm.outlier.barebones), plot(sm.outlier.semester))
```



```
summary(sm.outlier.barebones)
```

```
## Linear mixed-effects model fit by maximum likelihood
## Data: outlier.removed
##      AIC      BIC   logLik
## 6248.218 6291.835 -3117.109
##
## Random effects:
## Formula: ~1 | BARCS_ID
##             (Intercept) Residual
## StdDev: 0.001107774 0.6821351
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##     Phi1     Theta1
## 0.8633196 -0.3912553
## Fixed effects: GPA ~ Avg_Drinks_current + Avg_MJ_current
##                  Value Std.Error DF t-value p-value
## (Intercept) 3.0779332 0.019480592 2616 157.99999 0.0000
## Avg_Drinks_current -0.0012860 0.000453399 2616 -2.83632 0.0046
## Avg_MJ_current -0.0155962 0.002286148 2616 -6.82206 0.0000
## Correlation:
##             (Intr) Avg_D_
## Avg_Drinks_current -0.361
## Avg_MJ_current      -0.176 -0.263
##
## Standardized Within-Group Residuals:
##      Min        Q1        Med        Q3        Max
## -4.3069585 -0.5146944  0.1800863  0.7684056  1.9802361
```

```

## 
## Number of Observations: 3756
## Number of Groups: 1138

#summary(sm.outlier)
summary(sm.outlier.semester)

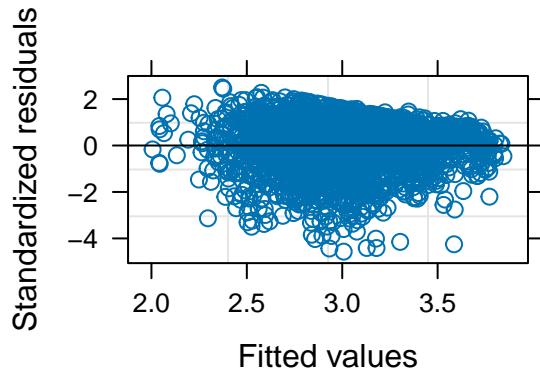
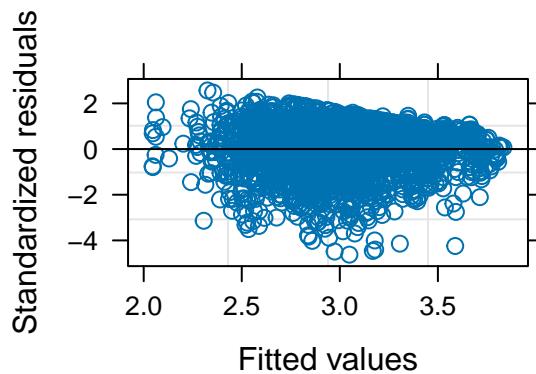
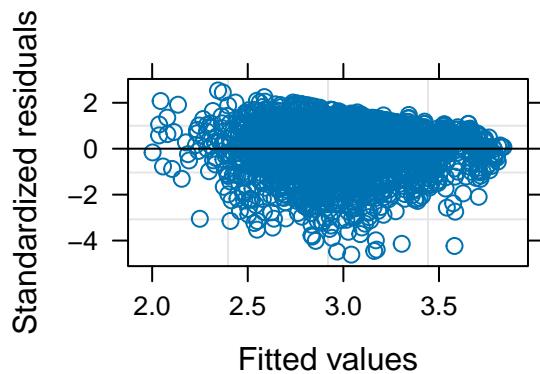
## Linear mixed-effects model fit by maximum likelihood
## Data: outlier.removed
##      AIC      BIC    logLik
## 6250.881 6356.81 -3108.441
##
## Random effects:
## Formula: ~1 | BARCS_ID
##             (Intercept) Residual
## StdDev: 0.0007011978 0.6808267
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##     Phi1     Theta1
## 0.8620453 -0.3876852
## Fixed effects: GPA ~ Avg_Drinks_current * Semester + Avg_Drinks_current * Avg_MJ_current +
##                 Value   Std.Error   DF   t-value p-value
## (Intercept) 3.0921511 0.024018646 2606 128.73961 0.0000
## Avg_Drinks_current -0.0019821 0.000706023 2606 -2.80741 0.0050
## Semester2 -0.0429750 0.021045932 2606 -2.04196 0.0413
## Semester3 -0.0062562 0.025555710 2606 -0.24480 0.8066
## Semester4 0.0356243 0.028799900 2606 1.23696 0.2162
## Avg_MJ_current -0.0200898 0.003853508 2606 -5.21338 0.0000
## Avg_Drinks_current:Semester2 0.0000677 0.000736687 2606 0.09195 0.9267
## Avg_Drinks_current:Semester3 0.0005484 0.000847947 2606 0.64676 0.5178
## Avg_Drinks_current:Semester4 -0.0000584 0.001035431 2606 -0.05642 0.9550
## Avg_Drinks_current:Avg_MJ_current 0.0000973 0.000048192 2606 2.01940 0.0435
## Semester2:Avg_MJ_current 0.0024561 0.003427459 2606 0.71658 0.4737
## Semester3:Avg_MJ_current 0.0007607 0.003990851 2606 0.19061 0.8488
## Semester4:Avg_MJ_current -0.0009391 0.004571833 2606 -0.20540 0.8373
## Correlation:
##                (Intr) Avg_D_ Smstr2 Smstr3 Smstr4 Av_MJ_
## Avg_Drinks_current -0.440
## Semester2 -0.451  0.274
## Semester3 -0.455  0.261  0.522
## Semester4 -0.465  0.251  0.447  0.563
## Avg_MJ_current -0.192 -0.124  0.028  0.024  0.023
## Avg_Drinks_current:Semester2 0.222 -0.547 -0.478 -0.250 -0.211  0.244
## Avg_Drinks_current:Semester3 0.236 -0.572 -0.263 -0.472 -0.259  0.254
## Avg_Drinks_current:Semester4 0.200 -0.480 -0.211 -0.246 -0.453  0.245
## Avg_Drinks_current:Avg_MJ_current 0.151 -0.322  0.023  0.033  0.042 -0.512
## Semester2:Avg_MJ_current 0.040  0.249 -0.082 -0.046 -0.039 -0.501
## Semester3:Avg_MJ_current 0.064  0.240 -0.043 -0.117 -0.062 -0.578
## Semester4:Avg_MJ_current 0.064  0.222 -0.037 -0.061 -0.112 -0.542
## A_D_:S2 A_D_:S3 A_D_:S4 A_D_:A S2:A_M S3:A_M
## Avg_Drinks_current
## Semester2
## Semester3

```

```

## Semester4
## Avg_MJ_current
## Avg_Drinks_current:Semester2
## Avg_Drinks_current:Semester3      0.539
## Avg_Drinks_current:Semester4      0.432   0.531
## Avg_Drinks_current:Avg_MJ_current -0.070 -0.082 -0.121
## Semester2:Avg_MJ_current        -0.442 -0.234 -0.188  0.029
## Semester3:Avg_MJ_current        -0.235 -0.387 -0.225  0.080  0.536
## Semester4:Avg_MJ_current        -0.197 -0.226 -0.393  0.060  0.452  0.581
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3       Max
## -4.2730021 -0.5229271  0.1921551  0.7756322  2.0421787
##
## Number of Observations: 3756
## Number of Groups: 1138
cowplot:::plot_grid(plot(fm.outlier.barebones), plot(fm.outlier), plot(fm.outlier.semester))

```



```
summary(fm.outlier.barebones)
```

```

## Linear mixed-effects model fit by maximum likelihood
##   Data: outlier.removed
##   AIC     BIC   logLik
## 5309.088 5412.924 -2637.544
##
## Random effects:
##   Formula: ~1 | BARCS_ID
##             (Intercept)  Residual

```

```

## StdDev: 0.0009925362 0.6290468
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##      Phi1      Theta1
## 0.8246318 -0.3752102
## Fixed effects: GPA ~ Avg_Drinks_current + Avg_MJ_current + Sex + Age1stround + SATMath + SATVerbal + SATWriting + Fager4_binarysmoker + FH_binarypositive + STAI_SELF_Total + BDI_SELF_Total + Parental_SES
##                                     Value Std.Error DF t-value p-value
## (Intercept)          0.18682546 0.6083329 2317 0.307111 0.7588
## Avg_Drinks_current -0.00159382 0.0004704 2317 -3.388435 0.0007
## Avg_MJ_current      -0.01514825 0.0023447 2317 -6.460674 0.0000
## Sexmale             -0.13850077 0.0360663 991 -3.840170 0.0001
## Age1stround         0.06236516 0.0324956 991 1.919186 0.0552
## SATMath             0.00133128 0.0002527 991 5.268060 0.0000
## SATVerbal           0.00038560 0.0003078 991 1.252914 0.2105
## SATWriting          0.00144282 0.0003283 991 4.395385 0.0000
## Fager4_binarysmoker -0.14269687 0.0608600 991 -2.344673 0.0192
## FH_binarypositive   -0.06371948 0.0402747 991 -1.582122 0.1139
## STAI_SELF_Total     0.00193731 0.0022782 991 0.850372 0.3953
## BDI_SELF_Total      -0.01099670 0.0050687 991 -2.169520 0.0303
## Parental_SES        0.00607179 0.0026733 991 2.271294 0.0233
## Correlation:
##                               (Intr) Avg_D_ Av_MJ_ Sexmal Ag1str SATMth SATVrb SATWrt
## Avg_Drinks_current    -0.005
## Avg_MJ_current        -0.020 -0.262
## Sexmale               0.088 -0.095 -0.086
## Age1stround           -0.968 -0.002 0.022 -0.106
## SATMath               0.008 -0.012 0.005 -0.245 -0.082
## SATVerbal              -0.023 0.012 -0.030 -0.081 -0.032 -0.135
## SATWriting             -0.116 -0.032 0.020 0.240 0.087 -0.407 -0.649
## Fager4_binarysmoker   0.048 -0.067 -0.116 -0.015 -0.062 0.038 0.025 -0.025
## FH_binarypositive      0.003 -0.025 -0.025 0.056 -0.021 0.061 -0.026 0.017
## STAI_SELF_Total        -0.121 0.029 -0.022 -0.036 -0.013 0.033 0.016 -0.020
## BDI_SELF_Total         0.074 -0.011 -0.029 0.089 0.000 0.016 -0.024 0.008
## Parental_SES          -0.091 0.073 0.017 0.043 0.003 -0.019 0.074 0.083
##                               Fgr4_b FH_bnr STAI_S BDI_SE
## Avg_Drinks_current
## Avg_MJ_current
## Sexmale
## Age1stround
## SATMath
## SATVerbal
## SATWriting
## Fager4_binarysmoker
## FH_binarypositive     0.028
## STAI_SELF_Total       -0.001 -0.038
## BDI_SELF_Total        -0.097 -0.064 -0.682
## Parental_SES          0.014 -0.051 -0.024 -0.021
##
## Standardized Within-Group Residuals:
##      Min      Q1      Med      Q3      Max
## -4.6125184 -0.4756358 0.1779168 0.7124774 2.5361775
##

```

```

## Number of Observations: 3321
## Number of Groups: 1002
summary(fm.outlier)

## Linear mixed-effects model fit by maximum likelihood
## Data: outlier.removed
##      AIC      BIC    logLik
## 5308.541 5418.486 -2636.271
##
## Random effects:
## Formula: ~1 | BARCS_ID
##             (Intercept) Residual
## StdDev: 0.0004757171 0.6292048
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##     Phi1     Theta1
## 0.8254541 -0.3758368
## Fixed effects: GPA ~ Avg_Drinks_current * Avg_MJ_current + Sex + Age1strround +
##                 Value Std.Error DF t-value p-value
## (Intercept)          0.22222125 0.6092770 2316 0.364729 0.7153
## Avg_Drinks_current -0.00204191 0.0005481 2316 -3.725714 0.0002
## Avg_MJ_current       -0.01810076 0.0029932 2316 -6.047314 0.0000
## Sexmale              -0.13895920 0.0361011 991 -3.849172 0.0001
## Age1strround         0.06094283 0.0325366 991 1.873056 0.0614
## SATMath              0.00132795 0.0002530 991 5.249645 0.0000
## SATVerbal            0.00038156 0.0003081 991 1.238562 0.2158
## SATWriting            0.00144591 0.0003286 991 4.400519 0.0000
## Fager4_binarysmoker -0.14026678 0.0609351 991 -2.301906 0.0215
## FH_binarypositive    -0.06212833 0.0403257 991 -1.540663 0.1237
## STAI_SELF_Total       0.00199227 0.0022806 991 0.873578 0.3826
## BDI_SELF_Total        -0.01130964 0.0050772 991 -2.227532 0.0261
## Parental_SES          0.00588563 0.0026784 991 2.197435 0.0282
## Avg_Drinks_current:Avg_MJ_current 0.00007987 0.0000501 2316 1.593727 0.1111
## Correlation:
## (Intr) Avg_D_ Av_MJ_ Sexmal Ag1str SATMth
## Avg_Drinks_current -0.023
## Avg_MJ_current     -0.038 0.143
## Sexmale             0.088 -0.078 -0.062
## Age1strround        -0.967 0.012 0.034 -0.106
## SATMath              0.008 -0.006 0.009 -0.245 -0.081
## SATVerbal            -0.023 0.014 -0.019 -0.081 -0.032 -0.135
## SATWriting            -0.116 -0.030 0.013 0.240 0.087 -0.407
## Fager4_binarysmoker 0.049 -0.071 -0.107 -0.015 -0.063 0.038
## FH_binarypositive    0.004 -0.035 -0.035 0.056 -0.022 0.061
## STAI_SELF_Total       -0.120 0.017 -0.027 -0.036 -0.013 0.033
## BDI_SELF_Total        0.073 0.010 0.001 0.089 0.001 0.016
## Parental_SES          -0.092 0.085 0.040 0.044 0.004 -0.019
## Avg_Drinks_current:Avg_MJ_current 0.036 -0.513 -0.622 -0.008 -0.027 -0.008
## SATVrb SATWrt Fgr4_b FH_bnr STAI_S BDI_SE
## Avg_Drinks_current
## Avg_MJ_current
## Sexmale

```

```

## Age1stround
## SATMath
## SATVerbal
## SATWriting          -0.649
## Fager4_binarysmoker 0.025 -0.025
## FH_binarypositive   -0.027  0.017  0.028
## STAI_SELF_Total      0.016 -0.020 -0.001 -0.037
## BDI_SELF_Total       -0.024  0.008 -0.097 -0.065 -0.682
## Parental_SES         0.074  0.083  0.012 -0.052 -0.024 -0.019
## Avg_Drinks_current:Avg_MJ_current -0.008  0.006  0.026  0.025  0.015 -0.038
## Pr_SES
## Avg_Drinks_current
## Avg_MJ_current
## Sexmale
## Age1stround
## SATMath
## SATVerbal
## SATWriting
## Fager4_binarysmoker
## FH_binarypositive
## STAI_SELF_Total
## BDI_SELF_Total
## Parental_SES
## Avg_Drinks_current:Avg_MJ_current -0.044
##
## Standardized Within-Group Residuals:
##      Min      Q1      Med      Q3      Max
## -4.6230206 -0.4745258  0.1756124  0.7147398  2.5663600
##
## Number of Observations: 3321
## Number of Groups: 1002
summary(fm.outlier.semester)

## Linear mixed-effects model fit by maximum likelihood
## Data: outlier.removed
##      AIC      BIC      logLik
## 5310.642 5475.559 -2628.321
##
## Random effects:
## Formula: ~1 | BARCS_ID
##           (Intercept) Residual
## StdDev: 0.0004696442 0.6276391
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | BARCS_ID
## Parameter estimate(s):
##      Phi1      Theta1
## 0.8244422 -0.3739730
## Fixed effects: GPA ~ Avg_Drinks_current * Semester + Avg_Drinks_current * Avg_MJ_current +
##                           Value Std.Error DF t-value p-value
## (Intercept)          0.22260394 0.6088037 2307 0.365642 0.7147
## Avg_Drinks_current -0.00226411 0.0007258 2307 -3.119266 0.0018
## Semester2            -0.03935074 0.0223030 2307 -1.764372 0.0778
## Semester3             0.00155149 0.0270167 2307 0.057427 0.9542

```

```

## Semester4          0.06019588 0.0303677 2307  1.982232  0.0476
## Avg_MJ_current   -0.01800074 0.0039510 2307 -4.555974  0.0000
## Sexmale           -0.13748502 0.0360670 991 -3.811933  0.0001
## Age1stround       0.06111667 0.0325014 991  1.880432  0.0603
## SATMath           0.00132484 0.0002527 991  5.242612  0.0000
## SATVerbal         0.00037541 0.0003078 991  1.219485  0.2230
## SATWriting        0.00145005 0.0003283 991  4.416195  0.0000
## Fager4_binarysmoker -0.13826913 0.0610062 991 -2.266478  0.0236
## FH_binarypositive -0.06109326 0.0402769 991 -1.516830  0.1296
## STAI_SELF_Total   0.00195276 0.0022777 991  0.857326  0.3915
## BDI_SELF_Total    -0.01122793 0.0050719 991 -2.213769  0.0271
## Parental_SES      0.00573799 0.0026760 991  2.144253  0.0323
## Avg_Drinks_current:Semester2 0.00028986 0.0007709 2307  0.376028  0.7069
## Avg_Drinks_current:Semester3 0.00083756 0.0008856 2307  0.945766  0.3444
## Avg_Drinks_current:Semester4 -0.00047438 0.0010939 2307 -0.433682  0.6646
## Avg_Drinks_current:Avg_MJ_current 0.00008139 0.0000504 2307  1.613905  0.1067
## Semester2:Avg_MJ_current 0.00128071 0.0036045 2307  0.355308  0.7224
## Semester3:Avg_MJ_current -0.00043675 0.0041809 2307 -0.104463  0.9168
## Semester4:Avg_MJ_current -0.00268707 0.0048897 2307 -0.549537  0.5827
## Correlation:
##                               (Intr) Avg_D_ Smstr2 Smstr3 Smstr4 Av_MJ_
## Avg_Drinks_current      -0.022
## Semester2                 -0.024  0.277
## Semester3                 -0.017  0.260  0.521
## Semester4                 -0.021  0.251  0.445  0.559
## Avg_MJ_current            -0.027 -0.109  0.037  0.032  0.037
## Sexmale                    0.088 -0.071 -0.010 -0.007 -0.004 -0.051
## Age1stround                -0.967  0.005  0.005 -0.001  0.003  0.025
## SATMath                     0.008  0.002 -0.002 -0.011 -0.002  0.000
## SATVerbal                  -0.023  0.028  0.008  0.010  0.008 -0.028
## SATWriting                 -0.116 -0.042 -0.006 -0.006 -0.008  0.024
## Fager4_binarysmoker        0.048 -0.057 -0.007 -0.011 -0.012 -0.112
## FH_binarypositive           0.004 -0.028 -0.003  0.000  0.003 -0.031
## STAI_SELF_Total             -0.120  0.016  0.000 -0.003 -0.002 -0.023
## BDI_SELF_Total              0.072 -0.001 -0.002  0.000  0.000  0.000
## Parental_SES                -0.092  0.075  0.009  0.007 -0.004  0.028
## Avg_Drinks_current:Semester2 0.008 -0.545 -0.472 -0.245 -0.206  0.232
## Avg_Drinks_current:Semester3 0.005 -0.565 -0.259 -0.468 -0.253  0.245
## Avg_Drinks_current:Semester4 0.001 -0.476 -0.204 -0.239 -0.458  0.217
## Avg_Drinks_current:Avg_MJ_current 0.035 -0.329  0.014  0.030  0.026 -0.516
## Semester2:Avg_MJ_current 0.005  0.234 -0.092 -0.050 -0.044 -0.497
## Semester3:Avg_MJ_current -0.003  0.223 -0.047 -0.127 -0.067 -0.577
## Semester4:Avg_MJ_current -0.004  0.205 -0.039 -0.062 -0.117 -0.521
## Sexmal Ag1str SATMth SATVrb SATWrt Fgr4_b
## Avg_Drinks_current
## Semester2
## Semester3
## Semester4
## Avg_MJ_current
## Sexmale
## Age1stround          -0.105
## SATMath               -0.245 -0.082
## SATVerbal              -0.081 -0.032 -0.134
## SATWriting             0.240  0.087 -0.408 -0.649

```

```

## Fager4_binarysmoker          -0.014 -0.061  0.038  0.025 -0.025
## FH_binarypositive           0.056 -0.022  0.061 -0.027  0.017  0.029
## STAI_SELF_Total             -0.036 -0.013  0.034  0.016 -0.020 -0.001
## BDI_SELF_Total              0.089  0.002  0.016 -0.024  0.008 -0.096
## Parental_SES                0.043  0.004 -0.019  0.074  0.082  0.012
## Avg_Drinks_current:Semester2 0.015  0.002 -0.006 -0.015  0.019 -0.006
## Avg_Drinks_current:Semester3 0.018  0.006 -0.005 -0.023  0.023  0.014
## Avg_Drinks_current:Semester4 0.013  0.009 -0.017 -0.028  0.031  0.011
## Avg_Drinks_current:Avg_MJ_current -0.008 -0.027 -0.007 -0.005  0.002  0.027
## Semester2:Avg_MJ_current     0.002 -0.005  0.010  0.007 -0.014  0.025
## Semester3:Avg_MJ_current     0.007  0.004  0.007  0.016 -0.017  0.041
## Semester4:Avg_MJ_current     0.005  0.004  0.012  0.025 -0.024  0.051
## FH_bnr STAI_S BDI_SE Pr_SES A_D_:S2 A_D_:S3
## Avg_Drinks_current
## Semester2
## Semester3
## Semester4
## Avg_MJ_current
## Sexmale
## Age1stround
## SATMath
## SATVerbal
## SATWriting
## Fager4_binarysmoker
## FH_binarypositive
## STAI_SELF_Total          -0.037
## BDI_SELF_Total            -0.065 -0.682
## Parental_SES              -0.052 -0.024 -0.019
## Avg_Drinks_current:Semester2 0.002 -0.003  0.012 -0.019
## Avg_Drinks_current:Semester3 0.006 -0.004  0.009 -0.019  0.532
## Avg_Drinks_current:Semester4 -0.001 -0.005  0.011  0.001  0.417  0.517
## Avg_Drinks_current:Avg_MJ_current 0.025  0.015 -0.038 -0.043 -0.057 -0.079
## Semester2:Avg_MJ_current    0.009  0.005 -0.007  0.008 -0.431 -0.223
## Semester3:Avg_MJ_current    0.002  0.004  0.007  0.002 -0.224 -0.370
## Semester4:Avg_MJ_current    0.005  0.001  0.002  0.002 -0.184 -0.212
## A_D_:S4 A_D_:A S2:A_M S3:A_M
## Avg_Drinks_current
## Semester2
## Semester3
## Semester4
## Avg_MJ_current
## Sexmale
## Age1stround
## SATMath
## SATVerbal
## SATWriting
## Fager4_binarysmoker
## FH_binarypositive
## STAI_SELF_Total
## BDI_SELF_Total
## Parental_SES
## Avg_Drinks_current:Semester2
## Avg_Drinks_current:Semester3
## Avg_Drinks_current:Semester4

```

```

## Avg_Drinks_current:Avg_MJ_current -0.081
## Semester2:Avg_MJ_current          -0.175   0.031
## Semester3:Avg_MJ_current          -0.211   0.088  0.523
## Semester4:Avg_MJ_current          -0.374   0.046  0.429  0.555
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3       Max
## -4.5687896 -0.4789052  0.1826912  0.7203899  2.5003249
##
## Number of Observations: 3321
## Number of Groups: 1002
AIC_sm.outlier <- AIC(sm.outlier.barebones, sm.outlier.semester, smsplines.ni, smsplines.1, smsplines.mix)
BIC_sm.outlier <- BIC(sm.outlier.barebones, sm.outlier.semester, smsplines.ni, smsplines.1, smsplines.mix)
df.sm.out <- data.frame(AIC_sm.outlier, BIC_sm.outlier)
df.sm.out[,-3]

##                  df      AIC      BIC
## sm.outlier.barebones 7 6248.218 6291.835
## sm.outlier.semester 17 6250.881 6356.810
## sm.splines.ni        8 6249.088 6298.937
## sm.splines.1         10 6247.954 6310.265
## sm.splines.mix       7 6247.088 6290.706

AIC_fm.outlier <- AIC(fm.outlier.barebones, fm.outlier, fm.outlier.semester)
BIC_fm.outlier <- BIC(fm.outlier.barebones, fm.outlier, fm.outlier.semester)
df.fm.out <- data.frame(AIC_fm.outlier, BIC_fm.outlier)
df.fm.out[,-3]

##                  df      AIC      BIC
## fm.outlier.barebones 17 5309.088 5412.924
## fm.outlier           18 5308.541 5418.486
## fm.outlier.semester 27 5310.642 5475.559

## probably useful to just make a table with the relevant coefficient values of the models

#Anova(sm.outlier, white.adjust = "hc3", correction = "Sidak")
#anova(sm.outlier, sm.outlier.barebones)

Anova(sm.outlier.semester, white.adjust = "hc3", correction = "Sidak")

## Analysis of Deviance Table (Type II tests)
##
## Response: GPA
##                  Chisq Df Pr(>Chisq)
## Avg_Drinks_current          7.7100 1   0.005492 **
## Semester                      11.3473 3   0.009989 **
## Avg_MJ_current                47.9558 1   4.359e-12 ***
## Avg_Drinks_current:Semester    0.6887 3   0.875852
## Avg_Drinks_current:Avg_MJ_current 4.0922 1   0.043083 *
## Semester:Avg_MJ_current       0.8705 3   0.832547
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
anova(sm.outlier.semester, sm.outlier.barebones)

##                  Model df      AIC      BIC      logLik     Test L.Ratio

```

```

## sm.outlier.semester      1 17 6250.881 6356.810 -3108.441
## sm.outlier.barebones     2  7 6248.218 6291.835 -3117.109 1 vs 2 17.3362
##          p-value
## sm.outlier.semester
## sm.outlier.barebones  0.0672
#anova(sm.outlier, sm.outlier.semester)

Anova(fm.outlier, white.adjust = "hc3", correction = "Sidak")

## Analysis of Deviance Table (Type II tests)
##
## Response: GPA
##                               Chisq Df Pr(>Chisq)
## Avg_Drinks_current           11.5278  1  0.0006856 ***
## Avg_MJ_current                41.8425  1  9.893e-11 ***
## Sex                           14.8789  1  0.0001146 ***
## Age1stround                   3.5232  1  0.0605158 .
## SATMath                        27.6754  1  1.435e-07 ***
## SATVerbal                      1.5405  1  0.2145388
## SATWriting                     19.4465  1  1.035e-05 ***
## Fager4_binary                  5.3212  1  0.0210674 *
## FH_binary                       2.3837  1  0.1226075
## STAI_SELF_Total                 0.7664  1  0.3813424
## BDI_SELF_Total                  4.9829  1  0.0255989 *
## Parental_SES                    4.8492  1  0.0276595 *
## Avg_Drinks_current:Avg_MJ_current 2.5507  1  0.1102441
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
anova(fm.outlier, fm.outlier.barebones)

##             Model df      AIC      BIC    logLik   Test  L.Ratio
## fm.outlier        1 18 5308.541 5418.486 -2636.271
## fm.outlier.barebones  2 17 5309.088 5412.924 -2637.544 1 vs 2 2.546134
##          p-value
## fm.outlier
## fm.outlier.barebones  0.1106
Anova(fm.outlier.semester, white.adjust = "hc3", correction = "Sidak")

## Analysis of Deviance Table (Type II tests)
##
## Response: GPA
##                               Chisq Df Pr(>Chisq)
## Avg_Drinks_current           11.1831  1  0.0008255 ***
## Semester                      12.1840  3  0.0067788 **
## Avg_MJ_current                42.8870  1  5.799e-11 ***
## Sex                            14.6322  1  0.0001307 ***
## Age1stround                   3.5607  1  0.0591634 .
## SATMath                        27.6767  1  1.434e-07 ***
## SATVerbal                      1.4975  1  0.2210540
## SATWriting                     19.6388  1  9.355e-06 ***
## Fager4_binary                  5.1727  1  0.0229439 *
## FH_binary                      2.3168  1  0.1279815

```

```

## STAI_SELF_Total          0.7401  1  0.3896178
## BDI_SELF_Total           4.9350  1  0.0263188 *
## Parental_SES             4.6299  1  0.0314196 *
## Avg_Drinks_current:Semester 2.0757  3  0.5568455
## Avg_Drinks_current:Avg_MJ_current 2.6229  1  0.1053347
## Semester:Avg_MJ_current    0.7350  3  0.8649489
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
anova(fm.outlier.semester, fm.outlier.barebones)

##                               Model df      AIC      BIC    logLik   Test  L.Ratio
## fm.outlier.semester      1 27 5310.642 5475.559 -2628.321
## fm.outlier.barebones     2 17 5309.088 5412.924 -2637.544 1 vs 2 18.44552
##                               p-value
## fm.outlier.semester
## fm.outlier.barebones  0.0479
anova(fm.outlier, fm.outlier.semester)

##                               Model df      AIC      BIC    logLik   Test  L.Ratio
## fm.outlier            1 18 5308.541 5418.486 -2636.271
## fm.outlier.semester    2 27 5310.642 5475.559 -2628.321 1 vs 2 15.89938
##                               p-value
## fm.outlier
## fm.outlier.semester  0.069

```

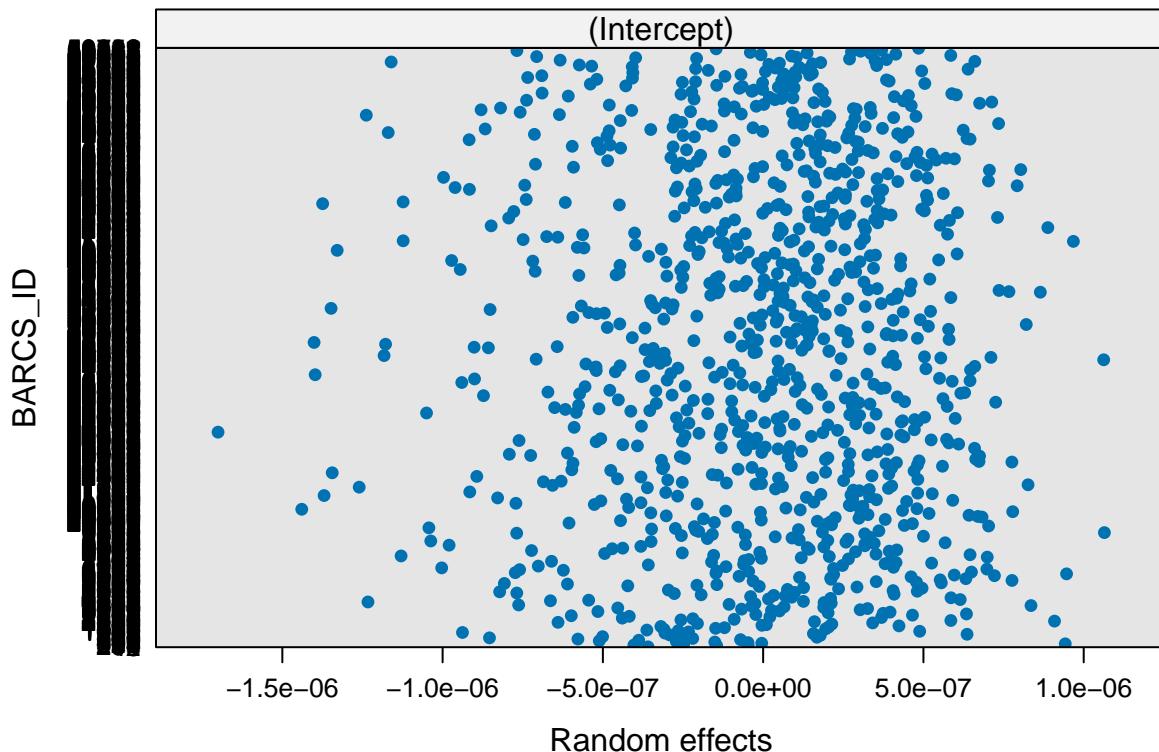
inclusion of the Interaction Effect leads to an stronger negative coefficients of the substance use parameters, but the interaction is always positive and not statistically significant. Models perform slightly better with the interaction effect, but the LRT test still rejects the inclusion for a pvalue =.05

```

plot(ranef(fm.outlier),
      main = "Random Intercept")

```

Random Intercept



```

dim(ranef(fm.outlier))

## [1] 1002      1

print(range(ranef(fm.outlier)))

## [1] -1.700540e-06  1.064521e-06

print(r.squaredGLMM(fm.outlier))

## Warning: 'r.squaredGLMM' now calculates a revised statistic. See the help page.

##           R2m          R2c
## [1,] 0.1815919 0.1815924

```

of course not.

Residuals:

```

fitted.fmout <- fitted(fm.outlier)
resid.fmout <- resid(fm.outlier)
df.fmout <- data.frame(fitted.fmout, resid.fmout)
ggplot.fmout <- ggplot(df.fmout, aes(x = fitted.fmout, y = resid.fmout)) +
  geom_point() +
  geom_smooth() +
  labs(title = "Residuals vs Fitted values Spline mix", x = "Fitted values", y = "Residuals") +
  theme_bw()
ggplot.fmout

## `geom_smooth()` using method = 'gam' and formula = 'y ~ s(x, bs = "cs")'
## Warning: Removed 1199 rows containing non-finite outside the scale range

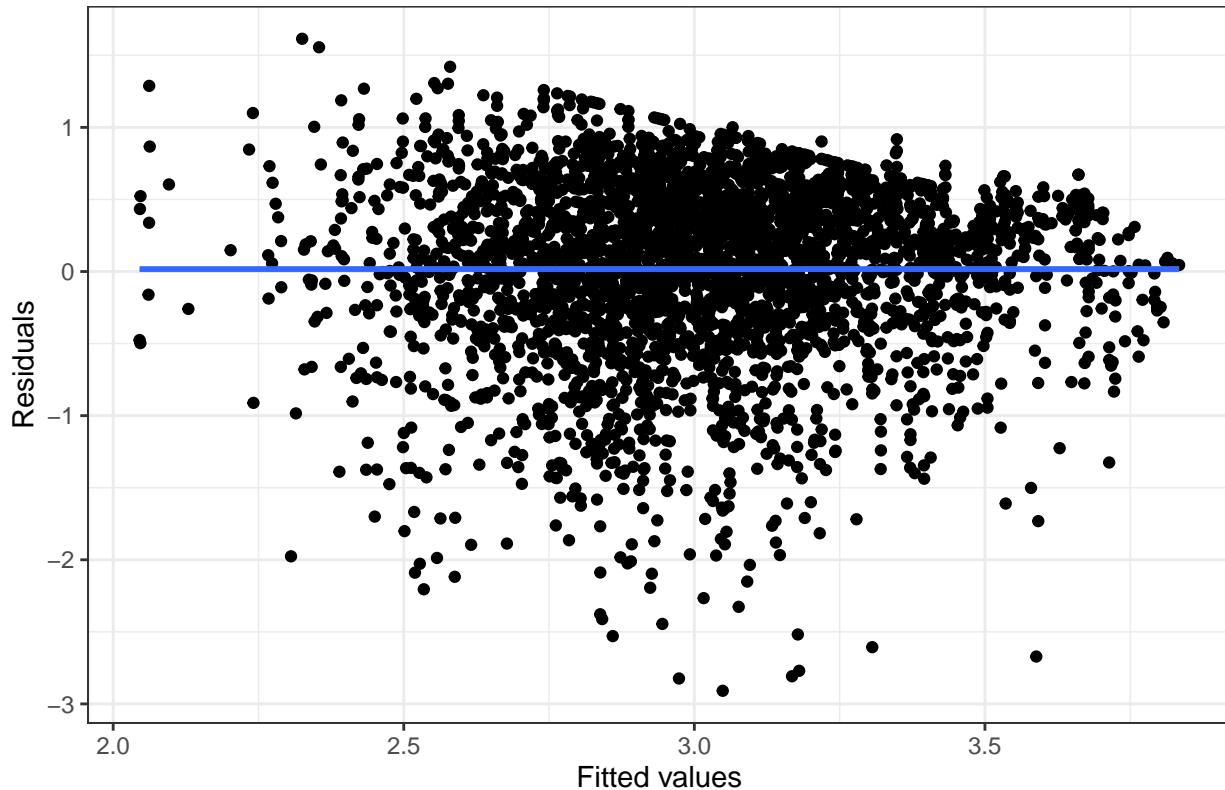
```

```

## (`stat_smooth()`).
## Warning: Removed 1199 rows containing missing values or values outside the scale range
## (`geom_point()`).

```

Residuals vs Fitted values Spline mix

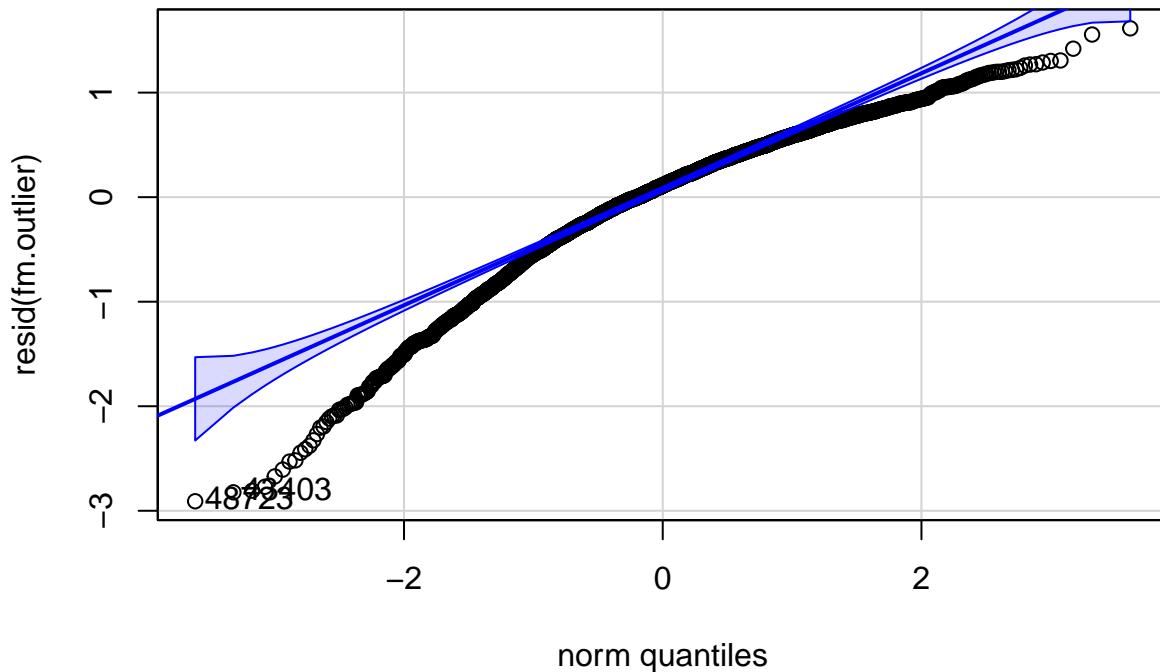


```

# plot(fitted(fm.outlier), resid(fm.outlier),
#       xlab = "Fitted Values",
#       ylab = "Residuals",
#       main = "Residuals vs Fitted Plot")
# abline(h = 0, col = "red")
qqPlot(resid(fm.outlier),
       main = "Normal Q-Q Plot of Residuals")

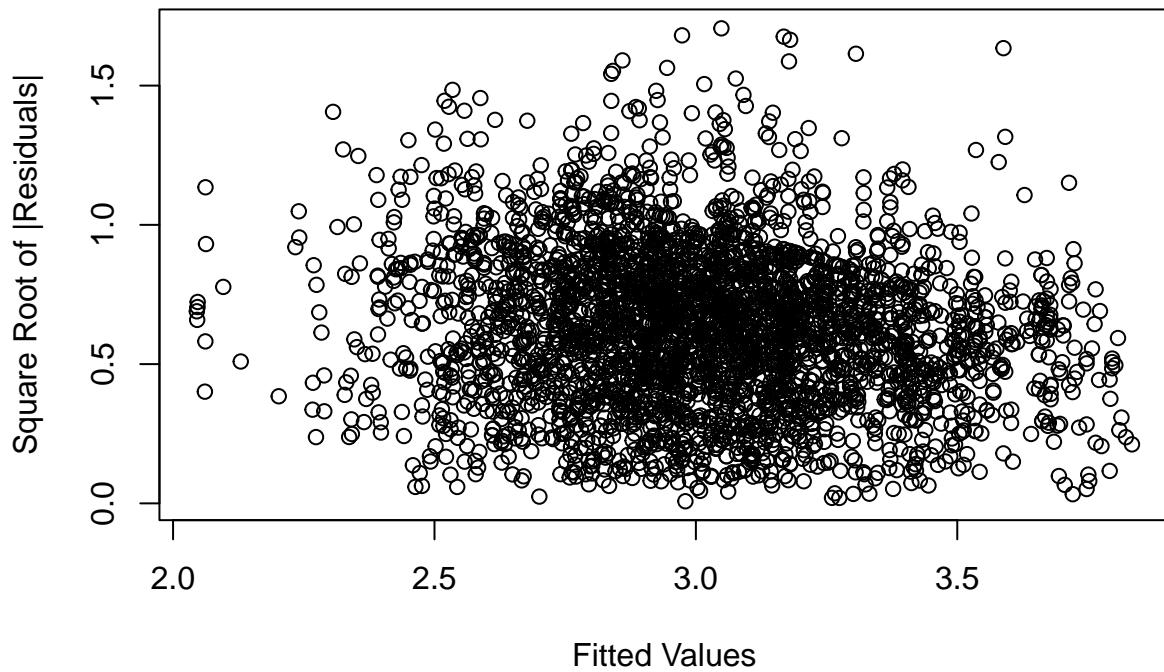
```

Normal Q-Q Plot of Residuals



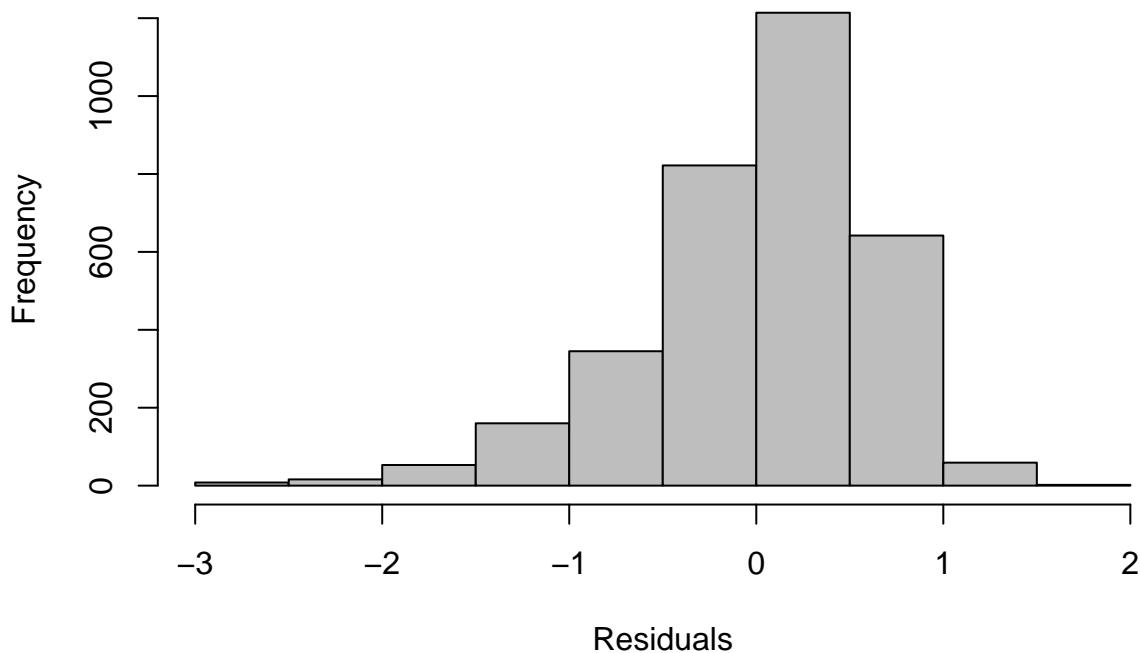
```
## 48723 43403
## 1400 1394
sqrt_abs_resid <- sqrt(abs(resid(fm.outlier)))
plot(fitted(fm.outlier), sqrt_abs_resid,
      xlab = "Fitted Values",
      ylab = "Square Root of |Residuals|",
      main = "Scale-Location Plot")
```

Scale–Location Plot



```
hist(resid(fm.outlier),  
     main = "Histogram of Residuals",  
     xlab = "Residuals",  
     breaks = 10,  
     col = "gray")
```

Histogram of Residuals



```

sm.outlier.barebones <- lme(GPA ~ Avg_Drinks_current + Avg_MJ_current, random = ~ 1 | BARCS_ID, data = o

sm.outlier.barebones.2 <- lme(GPA ~ Avg_Drinks_current + Avg_MJ_current, random = ~ 1 + Avg_Drinks_curre

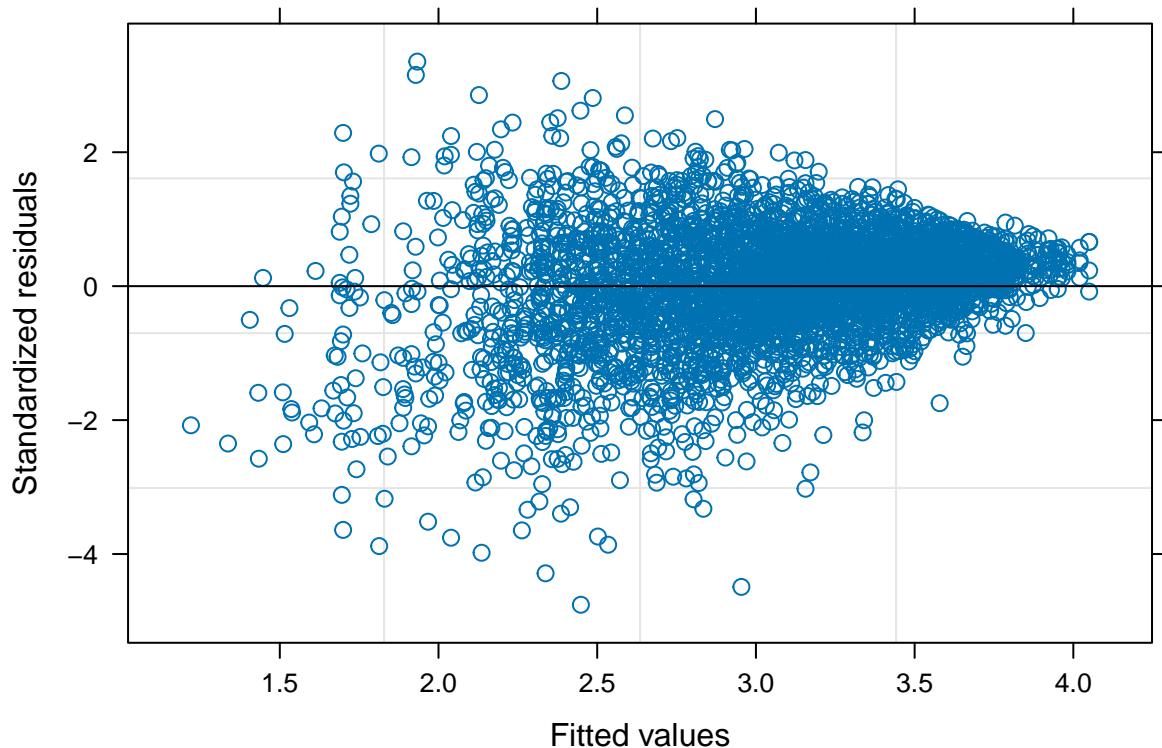
#sm.outlier.barebones.3 <- lme(GPA ~ Avg_Drinks_current + Avg_MJ_current, random = ~ 1 + Avg_Drinks_curre

anova(sm.outlier.barebones, sm.outlier.barebones.2)

##                               Model df      AIC      BIC    logLik   Test  L.Ratio
## sm.outlier.barebones     1  7 6278.447 6322.059 -3132.223
## sm.outlier.barebones.2   2 10 6360.955 6423.258 -3170.478 1 vs 2 76.50859
##                               p-value
## sm.outlier.barebones
## sm.outlier.barebones.2 <.0001

plot(sm.outlier.barebones.2)

```



```

sm.outlier.barebones <- lme(GPA ~ Avg_Drinks_current + Avg_MJ_current, random = ~ 1 | BARCS_ID, data = o

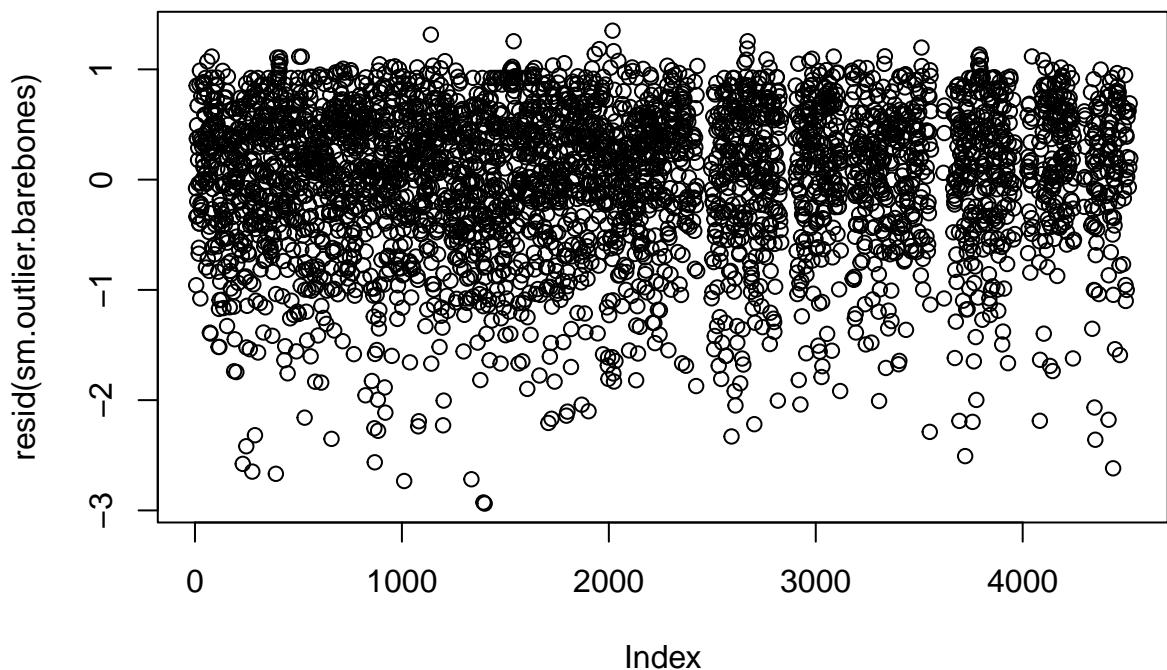
sm.outlier.barebones.2 <- lme(GPA ~ Avg_Drinks_current + Avg_MJ_current, random = ~ 1 + Avg_Drinks_curre

AIC(sm.outlier.barebones, sm.outlier.barebones.2)

##                      df      AIC
## sm.outlier.barebones    7 6248.218
## sm.outlier.barebones.2 10 6330.700

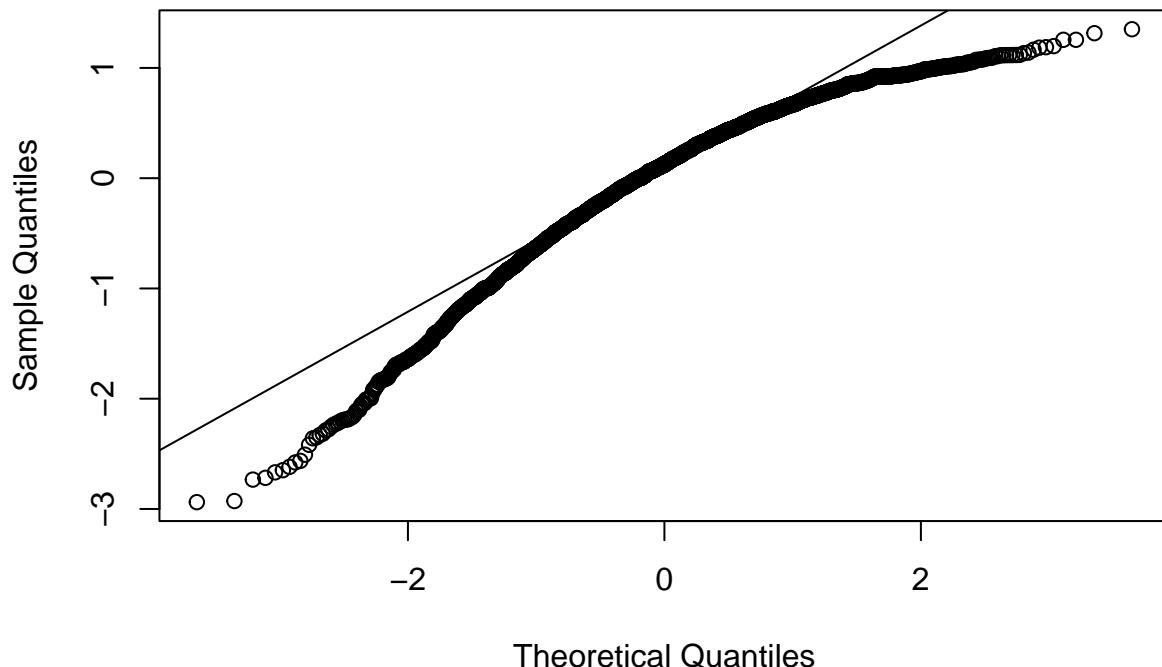
plot(resid(sm.outlier.barebones))

```

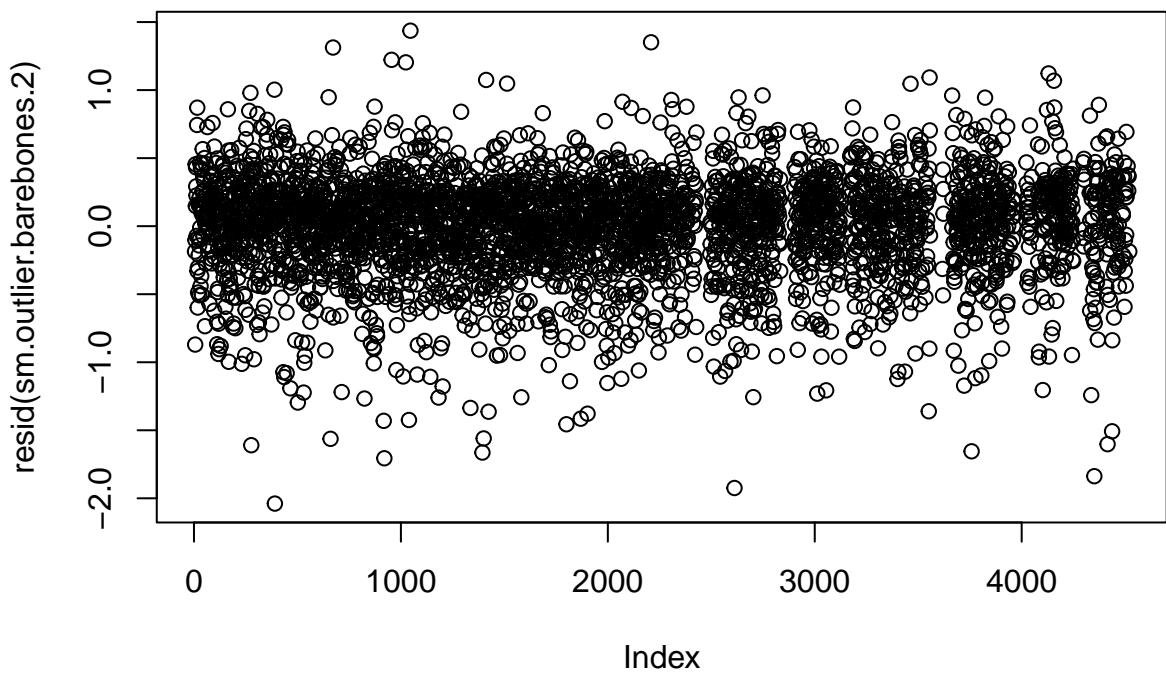


```
qqnorm(resid(sm.outlier.barebones))  
qqline(resid(sm.outlier.barebones))
```

Normal Q-Q Plot

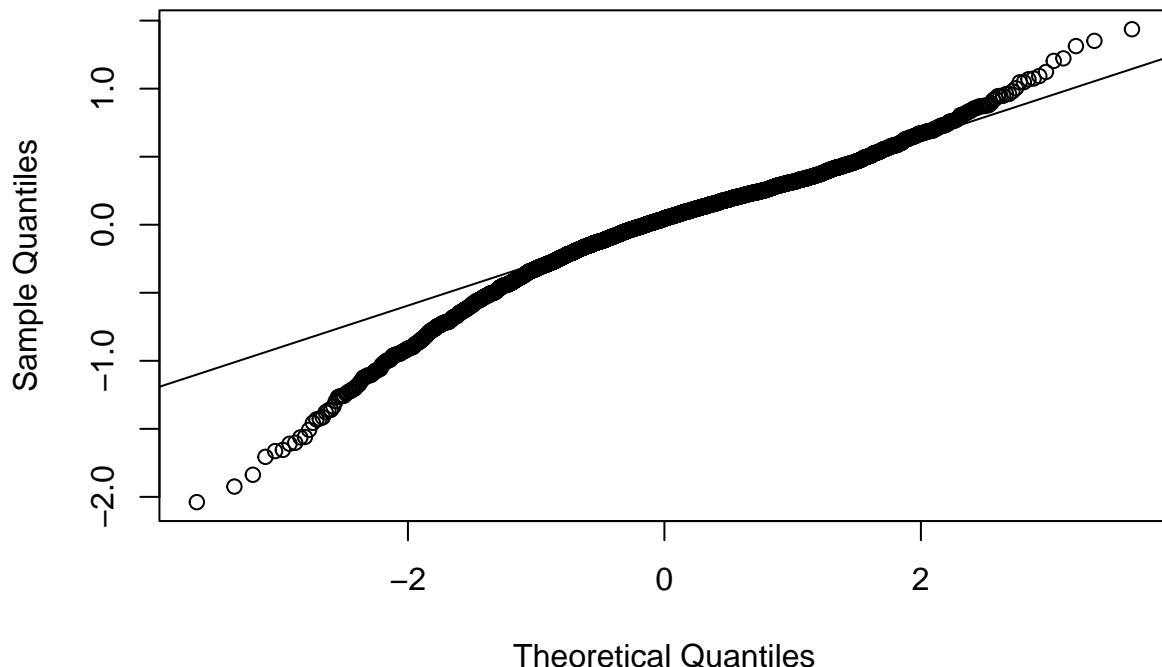


```
plot(resid(sm.outlier.barebones).2)
```



```
qqnorm(resid(sm.outlier.barebones.2))
qqline(resid(sm.outlier.barebones.2))
```

Normal Q-Q Plot



This

is also problematic, they aren't really nested.

```
fm.splines.ni <- gamm(
  GPA ~ s(Avg_Drinks_current, bs = "ps") + s(Avg_MJ_current, bs = "ps") + Sex + Age1stround + SATMath +
  data = outlier.removed,
  na.action = na.exclude,
```

```

correlation = corARMA(p = 1, q = 1, form = ~ Time | BARCS_ID)
)

fm.splines.1 <- gamm(
  GPA ~ te(Avg_Drinks_current, Avg_MJ_current, bs = "ps") + Sex + Age1stround + SATMath + SATVerbal + SATWriting + Fager4_binary + FH_binary + STAI_SELF_Total + BDI_SELF_Total + Parental_SES,
  random = list(BARCS_ID = ~ 1),
  data = outlier.removed,
  na.action = na.exclude,
  correlation = corARMA(p = 1, q = 1, form = ~ Time | BARCS_ID)
)

fm.splines.mix <- gamm(
  GPA ~ Avg_Drinks_current + s(Avg_MJ_current, bs = "ps") + Sex + Age1stround + SATMath + SATVerbal + SATWriting + Fager4_binary + FH_binary + STAI_SELF_Total + BDI_SELF_Total + Parental_SES,
  data = outlier.removed,
  na.action = na.exclude,
  correlation = corARMA(p = 1, q = 1, form = ~ Time | BARCS_ID)
)

fm.splines.mix.2 <- gamm(
  GPA ~ s(Avg_Drinks_current, bs = "ps") + Avg_MJ_current + Sex + Age1stround + SATMath + SATVerbal + SATWriting + Fager4_binary + FH_binary + STAI_SELF_Total + BDI_SELF_Total + Parental_SES,
  data = outlier.removed,
  na.action = na.exclude,
  correlation = corARMA(p = 1, q = 1, form = ~ Time | BARCS_ID)
)

summary(fm.splines.ni$gam)

## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length

## Warning in w * (as.numeric(object$y) - object$fitted.values): longer object
## length is not a multiple of shorter object length

##
## Family: gaussian
## Link function: identity
##
## Formula:
## GPA ~ s(Avg_Drinks_current, bs = "ps") + s(Avg_MJ_current, bs = "ps") +
##       Sex + Age1stround + SATMath + SATVerbal + SATWriting + Fager4_binary +
##       FH_binary + STAI_SELF_Total + BDI_SELF_Total + Parental_SES
##
## Parametric coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)          0.1205682  0.6084796   0.198  0.842942
## Sexmale             -0.1393115  0.0360835  -3.861  0.000115 ***
## Age1stround         0.0624473  0.0325076   1.921  0.054817 .
## SATMath              0.0013368  0.0002528   5.287 1.32e-07 ***
## SATVerbal            0.0003851  0.0003079   1.251  0.211053
## SATWriting           0.0014479  0.0003284   4.409 1.07e-05 ***
## Fager4_binarysmoker -0.1404159  0.0608989  -2.306  0.021188 *
## FH_binarypositive    -0.0630316  0.0402935  -1.564  0.117840
## STAI_SELF_Total      0.0019348  0.0022791   0.849  0.395969

```

```

## BDI_SELF_Total      -0.0111194  0.0050715  -2.193 0.028411 *
## Parental_SES        0.0058092  0.0026798   2.168 0.030245 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                      edf Ref.df      F p-value
## s(Avg_Drinks_current) 1.764  1.764  8.742 0.00282 **
## s(Avg_MJ_current)     1.244  1.244 33.906 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =      NA
## Scale est. = 0.39587   n = 3321
summary(fm.splines.ni$lme)

## Linear mixed-effects model fit by maximum likelihood
## Data: strip.offset(mf)
##          AIC      BIC    logLik
## 5310.356 5420.3 -2637.178
##
## Random effects:
## Formula: ~Xr - 1 | g
## Structure: pdIdnot
##             Xr1       Xr2       Xr3       Xr4       Xr5       Xr6
## StdDev: 0.005579746 0.005579746 0.005579746 0.005579746 0.005579746 0.005579746
##             Xr7       Xr8
## StdDev: 0.005579746 0.005579746
##
## Formula: ~Xr.0 - 1 | g.0 %in% g
## Structure: pdIdnot
##             Xr.01      Xr.02      Xr.03      Xr.04      Xr.05      Xr.06
## StdDev: 0.002447204 0.002447204 0.002447204 0.002447204 0.002447204 0.002447204
##             Xr.07      Xr.08 Residual
## StdDev: 0.002447204 0.002447204 0.6291795
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | g/g.0/BARCS_ID
## Parameter estimate(s):
##     Phi1     Theta1
## 0.824827 -0.374663
## Fixed effects: y ~ X - 1
##                  Value Std.Error DF t-value p-value
## X(Intercept)      0.1205682 0.6086635 3308 0.198087 0.8430
## XSexmale         -0.1393115 0.0360944 3308 -3.859648 0.0001
## XAge1stround     0.0624473 0.0325175 3308  1.920423 0.0549
## XSATMath          0.0013368 0.0002529 3308  5.285627 0.0000
## XSATVerbal        0.0003851 0.0003080 3308  1.250540 0.2112
## XSATWriting       0.0014479 0.0003285 3308  4.407720 0.0000
## XFager4_binarysmoker -0.1404159 0.0609173 3308 -2.305026 0.0212
## XFH_binarypositive -0.0630316 0.0403057 3308 -1.563838 0.1180
## XSTAI_SELF_Total   0.0019348 0.0022797 3308  0.848696 0.3961
## XBDI_SELF_Total    -0.0111194 0.0050731 3308 -2.191865 0.0285
## XParental_SES      0.0058092 0.0026806 3308  2.167151 0.0303

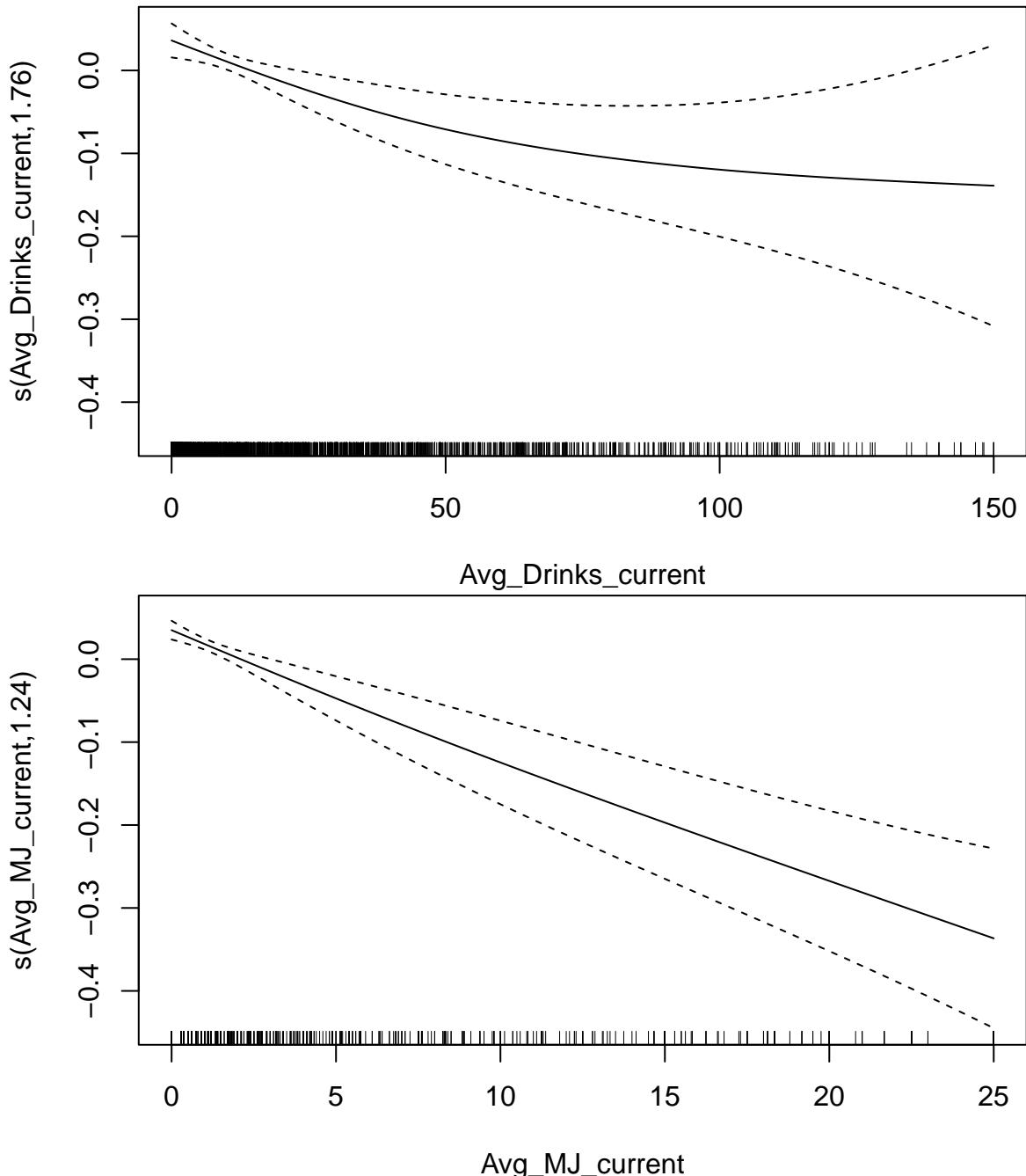
```

```

## Xs(Avg_Drinks_current)Fx1  0.3167301 0.1517983 3308  2.086519  0.0370
## Xs(Avg_MJ_current)Fx1      -0.6874989 0.1077795 3308 -6.378754  0.0000
## Correlation:
##                               X(Int) XSxml XAg1st XSATMt XSATVr XSATWr XFgr4_
## XSexmale                  0.086
## XAge1stround              -0.967 -0.106
## XSATMath                  0.008 -0.245 -0.082
## XSATVerbal                -0.023 -0.081 -0.032 -0.135
## XSATWriting               -0.117  0.239  0.087 -0.407 -0.649
## XFager4_binarysmoker     0.046 -0.015 -0.062  0.039  0.025 -0.025
## XFH_binarypositive        0.003  0.056 -0.021  0.062 -0.026  0.017  0.028
## XSTAI_SELF_Total          -0.121 -0.036 -0.013  0.033  0.016 -0.020 -0.001
## XBDI_SELF_Total           0.074  0.089  0.000  0.016 -0.024  0.008 -0.097
## XParental_SES             -0.089  0.044  0.003 -0.020  0.074  0.082  0.012
## Xs(Avg_Drinks_current)Fx1  0.000  0.082 -0.002  0.000 -0.007  0.023  0.043
## Xs(Avg_MJ_current)Fx1      -0.015 -0.086  0.022  0.006 -0.030  0.021 -0.115
##                               XFH_bn XSTAI_ XBDI_S XP_SES X(A_D_
## XSexmale
## XAge1stround
## XSATMath
## XSATVerbal
## XSATWriting
## XFager4_binarysmoker
## XFH_binarypositive
## XSTAI_SELF_Total          -0.038
## XBDI_SELF_Total           -0.064 -0.681
## XParental_SES             -0.051 -0.024 -0.020
## Xs(Avg_Drinks_current)Fx1  0.015 -0.026  0.019 -0.032
## Xs(Avg_MJ_current)Fx1      -0.024 -0.022 -0.030  0.014  0.192
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3       Max
## -4.6242243 -0.4745581  0.1739325  0.7095318  2.5565804
##
## Number of Observations: 3321
## Number of Groups:
##      g g.0 %in% g
##      1           1

plot.gam(fm.splines.ni$gam)

```



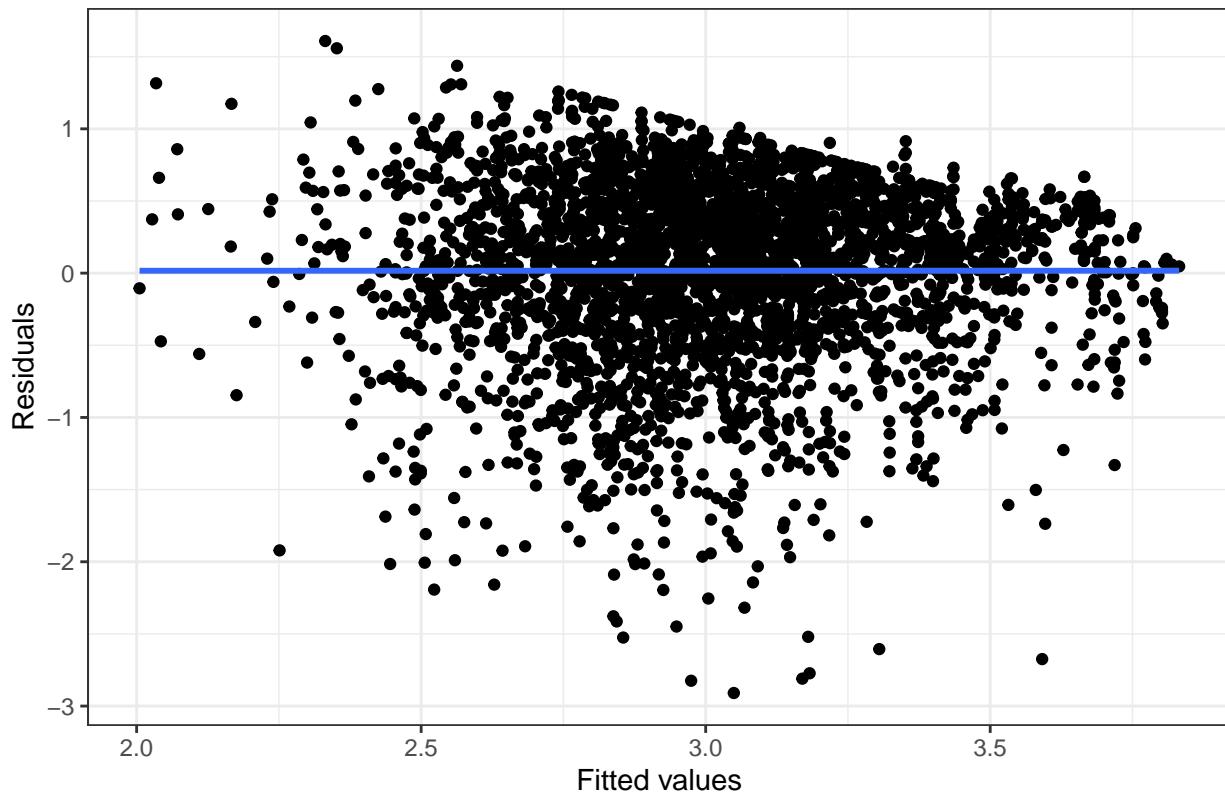
```

fm.fitted.ni <- fitted(fm.splines.ni$lme)
fm.resid.ni <- resid(fm.splines.ni$lme)
fm.df.ni <- data.frame(fm.fitted.ni, fm.resid.ni)
fm.ggplot.ni <- ggplot(fm.df.ni, aes(x = fm.fitted.ni, y = fm.resid.ni)) +
  geom_point() +
  geom_smooth() +
  labs(title = "Residuals vs Fitted values Spline mix (fm)", x = "Fitted values", y = "Residuals") +
  theme_bw()
fm.ggplot.ni

## `geom_smooth()` using method = 'gam' and formula = 'y ~ s(x, bs = "cs")'

```

Residuals vs Fitted values Spline mix (fm)



```
summary(fm.splines.1$gam)

## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length
## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length

##
## Family: gaussian
## Link function: identity
##
## Formula:
## GPA ~ te(Avg_Drinks_current, Avg_MJ_current, bs = "ps") + Sex +
##     Age1stround + SATMath + SATVerbal + SATWriting + Fager4_binary +
##     FH_binary + STAI_SELF_Total + BDI_SELF_Total + Parental_SES
##
## Parametric coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)            0.1552391  0.6087251  0.255 0.798721
## Sexmale              -0.1393582  0.0360833 -3.862 0.000115 ***
## Age1stround          0.0608744  0.0325189  1.872 0.061299 .
## SATMath              0.0013267  0.0002528  5.248 1.64e-07 ***
## SATVerbal             0.0003866  0.0003079  1.256 0.209335
## SATWriting            0.0014434  0.0003284  4.395 1.14e-05 ***
## Fager4_binarysmoker -0.1388333  0.0609131 -2.279 0.022718 *
## FH_binarypositive    -0.0620803  0.0403075 -1.540 0.123616
## STAI_SELF_Total       0.0019539  0.0022795  0.857 0.391432
## BDI_SELF_Total        -0.0111509  0.0050757 -2.197 0.028096 *
```

```

## Parental_SES          0.0058248  0.0026774   2.175 0.029663 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                                     edf Ref.df      F p-value
## te(Avg_Drinks_current,Avg_MJ_current) 3.887  3.887 19.09 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =      NA
## Scale est. = 0.39571    n = 3321
summary(fm.splines.1$lme)

## Linear mixed-effects model fit by maximum likelihood
## Data: strip.offset(mf)
##      AIC      BIC logLik
## 5311.898 5434.059 -2635.949
##
## Random effects:
## Formula: ~Xr - 1 | g
## Structure: pdTens
##             Xr1     Xr2     Xr3     Xr4     Xr5     Xr6     Xr7     Xr8
## StdDev: 15320.54 15298.44 5679.821 15311.27 15321.39 7637.938 2984.25 63.75789
##             Xr9     Xr10    Xr11    Xr12    Xr13    Xr14    Xr15    Xr16
## StdDev: 12693.94 5576.375 5551.013 1156.925 5580.912 5527.742 23.22421 685.2141
##             Xr17    Xr18    Xr19    Xr20    Xr21
## StdDev: 940.3771 962.3559 811.2201 4.004714 410.72
##
## Formula: ~1 | BARCS_ID %in% g
##           (Intercept) Residual
## StdDev: 0.007669674 0.629053
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | g/BARCS_ID
## Parameter estimate(s):
##            Phi1      Theta1
## 0.8251943 -0.3751729
## Fixed effects: y ~ X - 1
##                                         Value Std.Error DF t-value
## X(Intercept)                      0.1552391 0.6090012 2316 0.254908
## XSexmale                           -0.1393582 0.0360997 991 -3.860368
## XAge1stround                      0.0608744 0.0325336 991  1.871123
## XSATMath                          0.0013267 0.0002529 991  5.245214
## XSATVerbal                        0.0003866 0.0003081 991  1.255073
## XSATWriting                       0.0014434 0.0003286 991  4.393216
## XFager4_binarysmoker              -0.1388333 0.0609407 991 -2.278170
## XFH_binarypositive                -0.0620803 0.0403258 991 -1.539468
## XSTAI_SELF_Total                  0.0019539 0.0022806 991  0.856747
## XBDI_SELF_Total                  -0.0111509 0.0050780 991 -2.195914
## XParental_SES                   0.0058248 0.0026787 991  2.174512
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1 -0.9283674 0.1256135 2316 -7.390668
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2  0.0869171 0.1536186 2316  0.565798
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3 -0.9332627 0.2094837 2316 -4.455062

```

	p-value
##	
## X(Intercept)	0.7988
## XSxmale	0.0001
## XAge1stround	0.0616
## XSATMath	0.0000
## XSATVerbal	0.2097
## XSATWriting	0.0000
## XFager4_binarysmoker	0.0229
## XFH_binarypositive	0.1240
## XSTAI_SELF_Total	0.3918
## XBDI_SELF_Total	0.0283
## XParental_SES	0.0299
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1	0.0000
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2	0.5716
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3	0.0000
## Correlation:	
##	X(Int) XSxml XAg1st XSATMt XSATVr
## XSxmale	0.086
## XAge1stround	-0.968 -0.106
## XSATMath	0.008 -0.245 -0.081
## XSATVerbal	-0.023 -0.081 -0.032 -0.135
## XSATWriting	-0.116 0.240 0.087 -0.407 -0.649
## XFager4_binarysmoker	0.047 -0.015 -0.063 0.038 0.025
## XFH_binarypositive	0.003 0.056 -0.022 0.061 -0.027
## XSTAI_SELF_Total	-0.120 -0.036 -0.013 0.033 0.016
## XBDI_SELF_Total	0.073 0.089 0.001 0.016 -0.023
## XParental_SES	-0.091 0.044 0.004 -0.019 0.074
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1	-0.019 -0.099 0.027 0.005 -0.028
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2	-0.021 0.029 0.017 0.005 0.019
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3	0.015 -0.118 -0.007 -0.012 -0.004
##	XSATWr XFgr4_ XFH_bn XSTAI_ XBDI_S
## XSxmale	
## XAge1stround	
## XSATMath	
## XSATVerbal	
## XSATWriting	
## XFager4_binarysmoker	-0.025
## XFH_binarypositive	0.017 0.028
## XSTAI_SELF_Total	-0.020 -0.001 -0.037
## XBDI_SELF_Total	0.008 -0.097 -0.065 -0.682
## XParental_SES	0.083 0.012 -0.051 -0.024 -0.020
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1	0.015 -0.132 -0.032 -0.020 -0.027
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2	-0.015 0.012 -0.016 -0.005 0.046
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3	-0.019 -0.087 -0.016 0.021 -0.037
##	XP_SES X(A_D_,A_MJ_)F1
## XSxmale	
## XAge1stround	
## XSATMath	
## XSATVerbal	
## XSATWriting	
## XFager4_binarysmoker	
## XFH_binarypositive	
## XSTAI_SELF_Total	
## XBDI_SELF_Total	

```

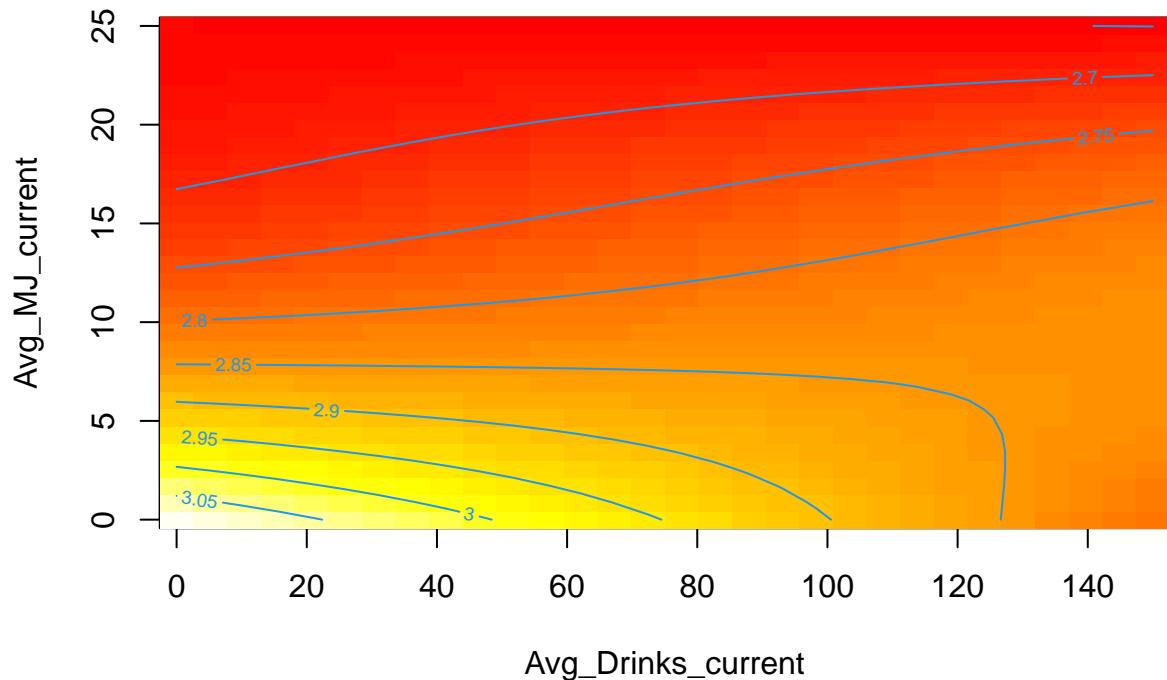
## XParental_SES
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1  0.036
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2  0.040 -0.199
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3  0.048  0.187
## X(A_D_,A_MJ_)F2
## XSexmale
## XAge1stround
## XSATMath
## XSATVerbal
## XSATWriting
## XFager4_binarysmoker
## XFH_binarypositive
## XSTAI_SELF_Total
## XBDI_SELF_Total
## XParental_SES
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx1
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx2
## Xte(Avg_Drinks_current,Avg_MJ_current)Fx3 -0.415
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3      Max
## -4.6283991 -0.4729682  0.1733176  0.7100734  2.5651594
##
## Number of Observations: 3321
## Number of Groups:
##      g BARCS_ID %in% g
##      1          1002

plot.gam(fm.splines.1$gam)

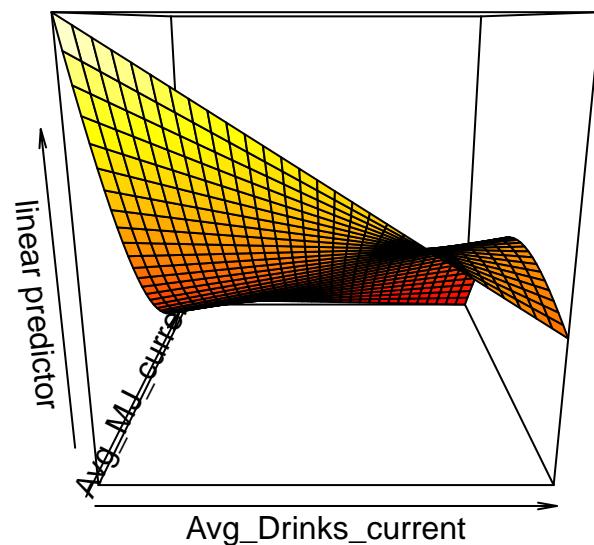


```

linear predictor



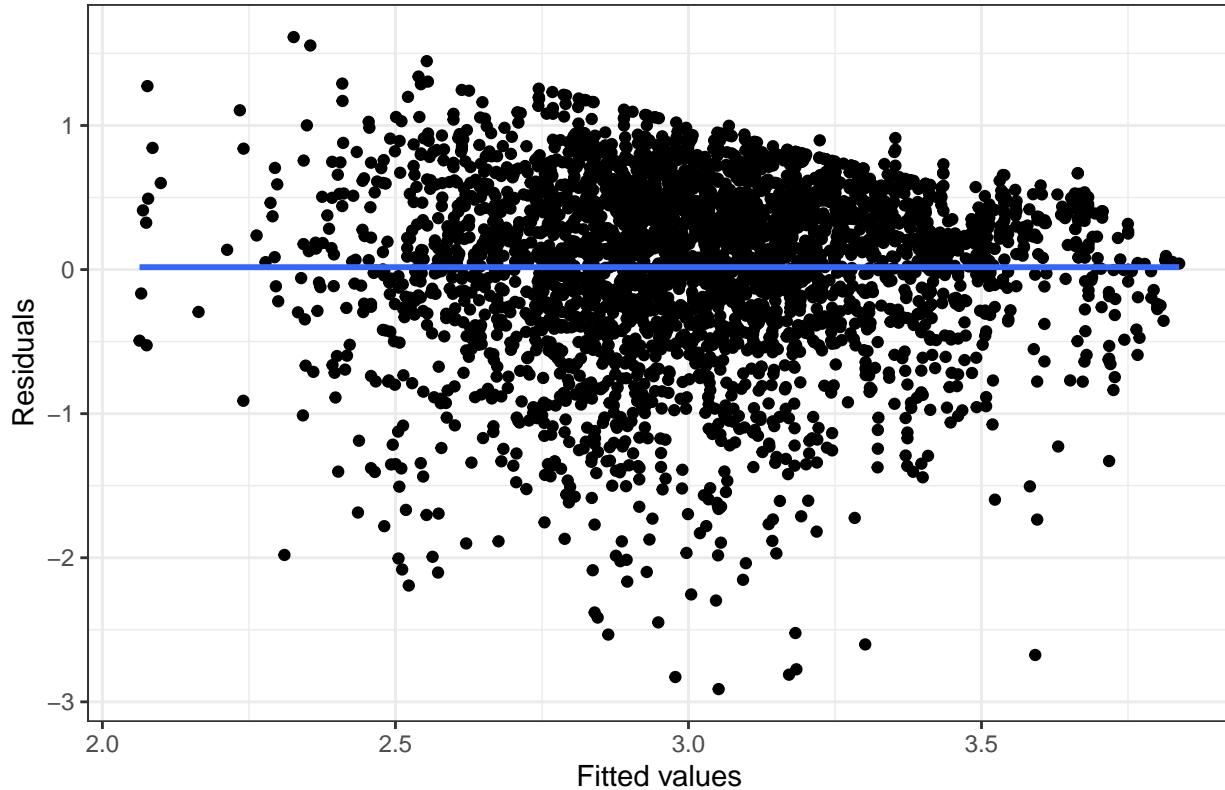
```
vis.gam(sm.splines.1$gam, view = c("Avg_Drinks_current", "Avg_MJ_current"), plot.type = "persp")
```



```
fm.fitted.1 <- fitted(fm.splines.1$lme)
fm.resid.1 <- resid(fm.splines.1$lme)
fm.df.1 <- data.frame(fm.fitted.1, fm.resid.1)
fm.ggplot.1 <- ggplot(fm.df.1, aes(x = fm.fitted.1, y = fm.resid.1)) +
  geom_point() +
  geom_smooth() +
  labs(title = "Residuals vs Fitted values Spline mix (fm)", x = "Fitted values", y = "Residuals") +
  theme_bw()
fm.ggplot.1
```

```
## `geom_smooth()` using method = 'gam' and formula = 'y ~ s(x, bs = "cs")'
```

Residuals vs Fitted values Spline mix (fm)



```
summary(fm.splines.mix$gam)
```

```
## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length
## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length

##
## Family: gaussian
## Link function: identity
##
## Formula:
## GPA ~ Avg_Drinks_current + s(Avg_MJ_current, bs = "ps") + Sex +
##     Age1stround + SATMath + SATVerbal + SATWriting + Fager4_binary +
##     FH_binary + STAI_SELF_Total + BDI_SELF_Total + Parental_SES
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.1522100  0.6081217  0.250 0.802375
## Avg_Drinks_current -0.0015552  0.0004725 -3.291 0.001008 **
## Sexmale      -0.1388101  0.0360603 -3.849 0.000121 ***
## Age1stround   0.0623631  0.0324888  1.920 0.055004 .
## SATMath       0.0013297  0.0002527  5.263 1.51e-07 ***
## SATVerbal     0.0003878  0.0003077  1.260 0.207670
## SATWriting    0.0014425  0.0003282  4.395 1.14e-05 ***
## Fager4_binarysmoker -0.1420863  0.0608523 -2.335 0.019606 *
```

```

## FH_binarypositive -0.0639473 0.0402671 -1.588 0.112364
## STAI_SELF_Total 0.0019356 0.0022777 0.850 0.395499
## BDI_SELF_Total -0.0109579 0.0050678 -2.162 0.030670 *
## Parental_SES 0.0060329 0.0026732 2.257 0.024085 *
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##          edf Ref.df   F p-value
## s(Avg_MJ_current) 1.464 1.464 30.4 <2e-16 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =      NA
## Scale est. = 0.39563 n = 3321
summary(fm.splines.mix$lm)

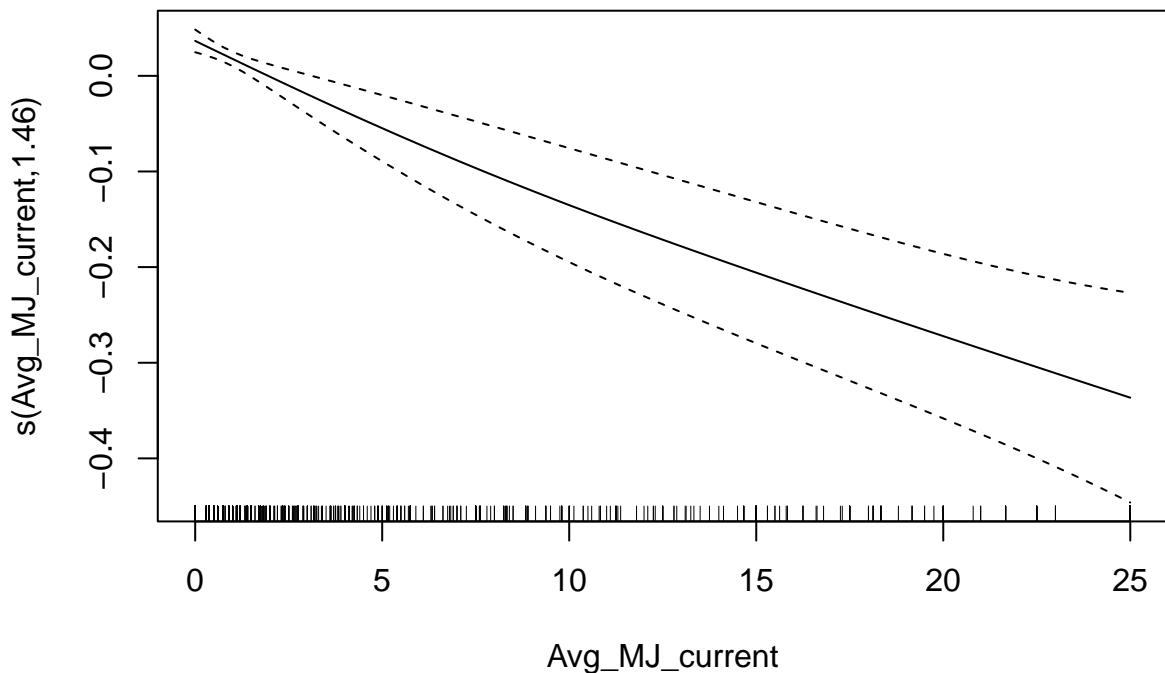
## Linear mixed-effects model fit by maximum likelihood
## Data: strip.offset(mf)
##      AIC    BIC   logLik
## 5308.963 5412.8 -2637.482
##
## Random effects:
## Formula: ~Xr - 1 | g
## Structure: pdIdnot
##             Xr1        Xr2        Xr3        Xr4        Xr5        Xr6
## StdDev: 0.003732819 0.003732819 0.003732819 0.003732819 0.003732819 0.003732819
##             Xr7        Xr8 Residual
## StdDev: 0.003732819 0.003732819 0.628995
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | g/BARCS_ID
## Parameter estimate(s):
##     Phi1     Theta1
## 0.8246106 -0.3751304
## Fixed effects: y ~ X - 1
##                  Value Std.Error DF t-value p-value
## X(Intercept) 0.1522100 0.6082136 3308 0.250258 0.8024
## XAvg_Drinks_current -0.0015552 0.0004726 3308 -3.290672 0.0010
## XSexmale -0.1388101 0.0360658 3308 -3.848803 0.0001
## XAge1stround 0.0623631 0.0324937 3308 1.919234 0.0550
## XSATMath 0.0013297 0.0002527 3308 5.261995 0.0000
## XSATVerbal 0.0003878 0.0003078 3308 1.260054 0.2077
## XSATWriting 0.0014425 0.0003282 3308 4.394760 0.0000
## XFager4_binarysmoker -0.1420863 0.0608615 3308 -2.334582 0.0196
## XFH_binarypositive -0.0639473 0.0402732 3308 -1.587840 0.1124
## XSTAI_SELF_Total 0.0019356 0.0022781 3308 0.849670 0.3956
## XBDI_SELF_Total -0.0109579 0.0050686 3308 -2.161925 0.0307
## XParental_SES 0.0060329 0.0026736 3308 2.256470 0.0241
## Xs(Avg_MJ_current)Fx1 -0.6960098 0.1078174 3308 -6.455448 0.0000
## Correlation:
##                  X(Int) XAv_D_ XSexml XAg1st XSATMt XSATVr XSATWr XFgr4_
## XAvg_Drinks_current -0.007
## XSexmale 0.087 -0.096

```

```

## XAge1stround      -0.967 -0.002 -0.106
## XSATMath          0.008 -0.012 -0.245 -0.082
## XSATVerbal        -0.023  0.013 -0.081 -0.032 -0.135
## XSATWriting       -0.116 -0.032  0.240  0.087 -0.407 -0.649
## XFager4_binarysmoker 0.047 -0.065 -0.015 -0.062  0.038  0.025 -0.025
## XFH_binarypositive 0.003 -0.026  0.056 -0.021  0.062 -0.026  0.017  0.027
## XSTAI_SELF_Total   -0.121  0.029 -0.036 -0.013  0.033  0.016 -0.020 -0.001
## XBDI_SELF_Total    0.074 -0.010  0.089  0.000  0.016 -0.024  0.008 -0.096
## XParental_SES     -0.090  0.070  0.044  0.003 -0.019  0.074  0.083  0.013
## Xs(Avg_MJ_current)Fx1 -0.011 -0.261 -0.086  0.022  0.005 -0.030  0.021 -0.116
##                               XFH_bn XSTAI_ XBDI_S XP_SES
## XAvg_Drinks_current
## XSexmale
## XAge1stround
## XSATMath
## XSATVerbal
## XSATWriting
## XFager4_binarysmoker
## XFH_binarypositive
## XSTAI_SELF_Total      -0.038
## XBDI_SELF_Total       -0.064 -0.682
## XParental_SES        -0.050 -0.024 -0.021
## Xs(Avg_MJ_current)Fx1 -0.025 -0.022 -0.029  0.016
##
## Standardized Within-Group Residuals:
##      Min        Q1        Med        Q3        Max
## -4.6150949 -0.4759343  0.1792249  0.7120703  2.5363837
##
## Number of Observations: 3321
## Number of Groups: 1
plot.gam(fm.splines.mix$gam)

```



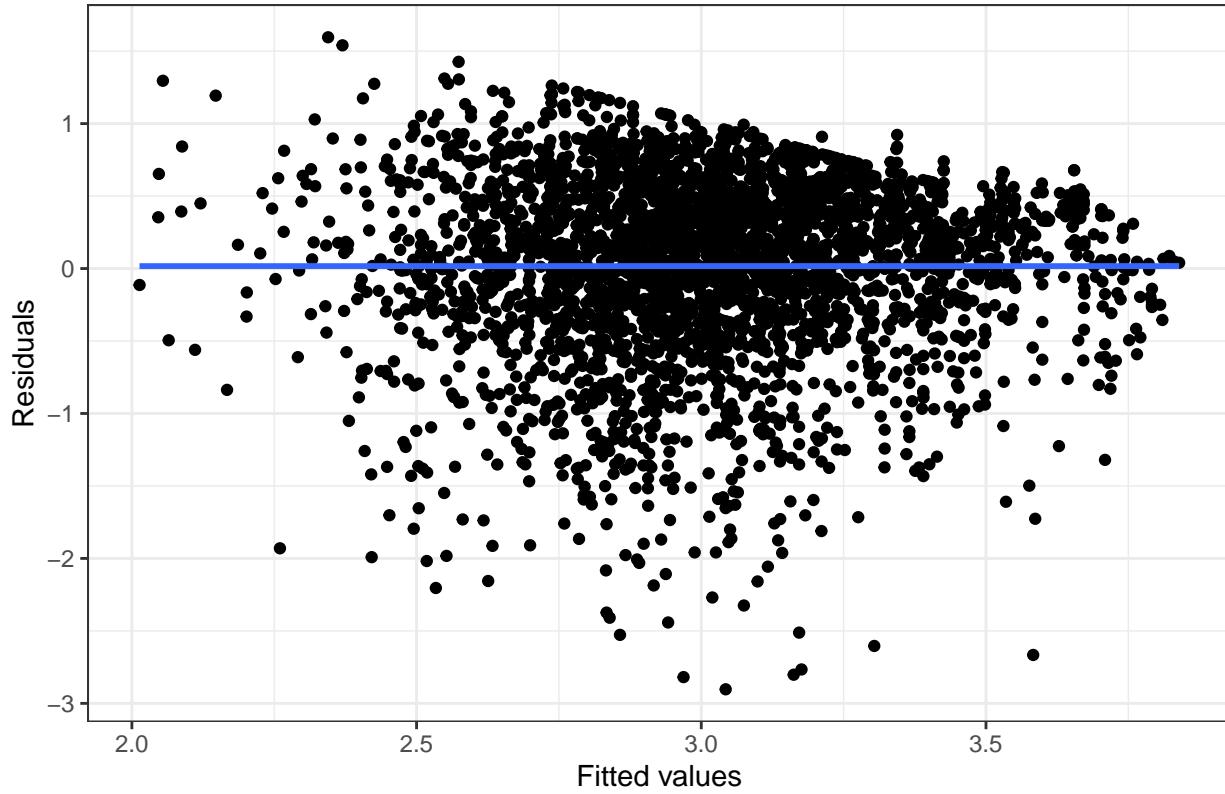
```

fm.fitted.mix <- fitted(fm.splines.mix$lme)
fm.resid.mix <- resid(fm.splines.mix$lme)
fm.df.mix <- data.frame(fm.fitted.mix, fm.resid.mix)
fm.ggplot.mix <- ggplot(fm.df.mix, aes(x = fm.fitted.mix, y = fm.resid.mix)) +
  geom_point() +
  geom_smooth() +
  labs(title = "Residuals vs Fitted values Spline mix (fm)", x = "Fitted values", y = "Residuals") +
  theme_bw()
fm.ggplot.mix

## `geom_smooth()` using method = 'gam' and formula = 'y ~ s(x, bs = "cs")'

```

Residuals vs Fitted values Spline mix (fm)



```

summary(fm.splines.mix.2$gam)

## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length
## Warning in as.numeric(object$y) - object$fitted.values: longer object length is
## not a multiple of shorter object length

##
## Family: gaussian
## Link function: identity
##
## Formula:
## GPA ~ s(Avg_Drinks_current, bs = "ps") + Avg_MJ_current + Sex +
##     Age1stround + SATMath + SATVerbal + SATWriting + Fager4_binary +
##     FH_binary + STAI_SELF_Total + BDI_SELF_Total + Parental_SES
##

```

```

## Parametric coefficients:
##                               Estimate Std. Error t value Pr(>|t|)
## (Intercept)            0.1541499  0.6087058   0.253 0.800097
## Avg_MJ_current       -0.0149718  0.0023471  -6.379 2.03e-10 ***
## Sexmale              -0.1391912  0.0360901  -3.857 0.000117 ***
## Age1stround          0.0624535  0.0325142   1.921 0.054842 .
## SATMath              0.0013378  0.0002529   5.290 1.30e-07 ***
## SATVerbal             0.0003841  0.0003079   1.247 0.212426
## SATWriting            0.0014483  0.0003285   4.409 1.07e-05 ***
## Fager4_binarysmoker -0.1406170  0.0609095  -2.309 0.021026 *
## FH_binarypositive    -0.0628868  0.0403011  -1.560 0.118755
## STAI_SELF_Total       0.0019353  0.0022795   0.849 0.395944
## BDI_SELF_Total        -0.0111436  0.0050724  -2.197 0.028098 *
## Parental_SES          0.0058180  0.0026803   2.171 0.030028 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##          edf Ref.df      F p-value
## s(Avg_Drinks_current) 1.789  1.789 8.915 0.00234 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =      NA
## Scale est. =  0.3959    n = 3321
summary(fm.splines.mix.2$lme)

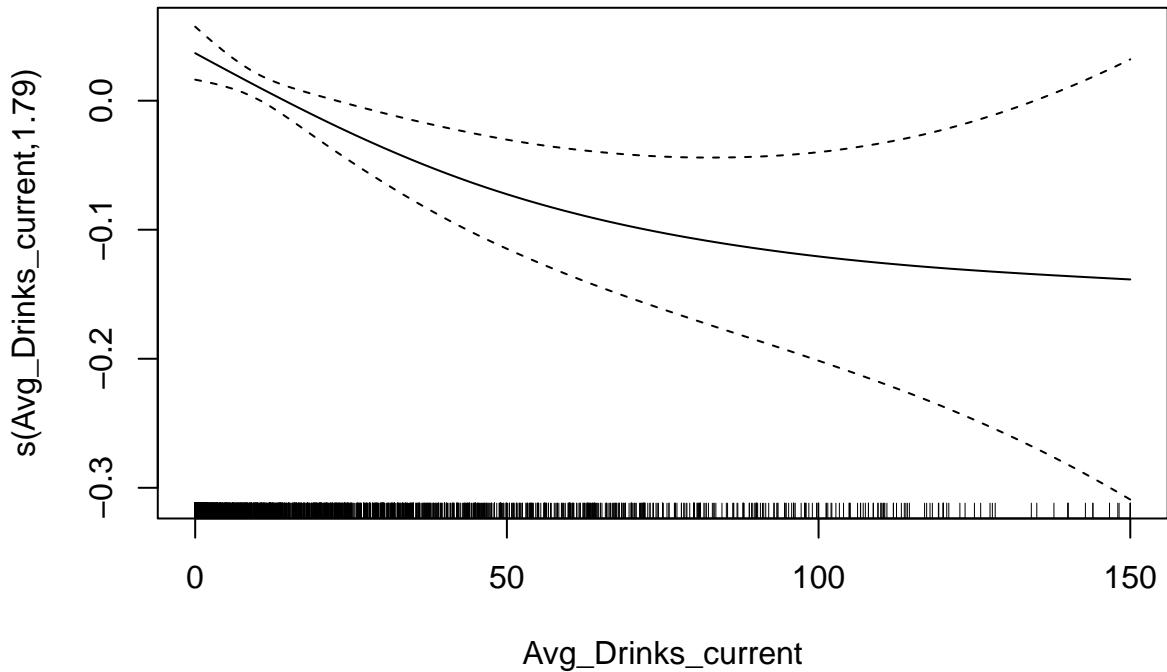
## Linear mixed-effects model fit by maximum likelihood
## Data: strip.offset(mf)
##      AIC      BIC      logLik
## 5308.382 5412.219 -2637.191
##
## Random effects:
## Formula: ~Xr - 1 | g
## Structure: pdIdnot
##           Xr1        Xr2        Xr3        Xr4        Xr5        Xr6
## StdDev: 0.005735126 0.005735126 0.005735126 0.005735126 0.005735126 0.005735126
##           Xr7        Xr8  Residual
## StdDev: 0.005735126 0.005735126 0.6292087
##
## Correlation Structure: ARMA(1,1)
## Formula: ~Time | g/BARCS_ID
## Parameter estimate(s):
##     Phi1     Theta1
## 0.8248470 -0.3746877
## Fixed effects: y ~ X - 1
##                  Value Std.Error DF t-value p-value
## X(Intercept)      0.1541499 0.6087978 3308 0.253204 0.8001
## XAvg_MJ_current  -0.0149718 0.0023475 3308 -6.377879 0.0000
## XSexmale          -0.1391912 0.0360956 3308 -3.856184 0.0001
## XAge1stround      0.0624535 0.0325191 3308  1.920514 0.0549
## XSATMath           0.0013378 0.0002529 3308  5.289393 0.0000
## XSATVerbal         0.0003841 0.0003080 3308  1.246974 0.2125
## XSATWriting        0.0014483 0.0003285 3308  4.408528 0.0000

```

```

## XFager4_binarysmoker      -0.1406170 0.0609187 3308 -2.308275  0.0210
## XFH_binarypositive        -0.0628868 0.0403072 3308 -1.560189  0.1188
## XSTAI_SELF_Total          0.0019353 0.0022799 3308  0.848870  0.3960
## XBDI_SELF_Total           -0.0111436 0.0050732 3308 -2.196554  0.0281
## XParental_SES             0.0058180 0.0026807 3308  2.170336  0.0301
## Xs(Avg_Drinks_current)Fx1 0.3174258 0.1524449 3308  2.082234  0.0374
## Correlation:
##                               X(Int) XA_MJ_ XSexml XAg1st XSATMt XSATVr XSATWr
## XAvg_MJ_current            -0.024
## XSexmale                   0.087 -0.086
## XAge1stround               -0.968  0.023 -0.106
## XSATMath                    0.008  0.006 -0.245 -0.082
## XSATVerbal                  -0.022 -0.030 -0.081 -0.032 -0.135
## XSATWriting                 -0.117  0.021  0.239  0.087 -0.407 -0.649
## XFager4_binarysmoker       0.047 -0.114 -0.015 -0.062  0.039  0.025 -0.025
## XFH_binarypositive          0.003 -0.024  0.056 -0.021  0.062 -0.026  0.017
## XSTAI_SELF_Total            -0.121 -0.022 -0.036 -0.013  0.033  0.016 -0.020
## XBDI_SELF_Total             0.074 -0.030  0.089  0.000  0.016 -0.024  0.008
## XParental_SES              -0.089  0.014  0.044  0.003 -0.020  0.074  0.082
## Xs(Avg_Drinks_current)Fx1 -0.002  0.190  0.081 -0.002  0.000 -0.007  0.023
##                               XFgr4_ XFH_bn XSTAI_ XBDI_S XP_SES
## XAvg_MJ_current
## XSexmale
## XAge1stround
## XSATMath
## XSATVerbal
## XSATWriting
## XFager4_binarysmoker
## XFH_binarypositive         0.028
## XSTAI_SELF_Total           -0.001 -0.038
## XBDI_SELF_Total            -0.097 -0.064 -0.681
## XParental_SES              0.012 -0.051 -0.024 -0.020
## Xs(Avg_Drinks_current)Fx1 0.043  0.014 -0.026  0.019 -0.032
##
## Standardized Within-Group Residuals:
##      Min       Q1       Med       Q3       Max
## -4.6234526 -0.4740644  0.1749082  0.7104452  2.5573321
##
## Number of Observations: 3321
## Number of Groups: 1
plot.gam(fm.splines.mix.2$gam)

```



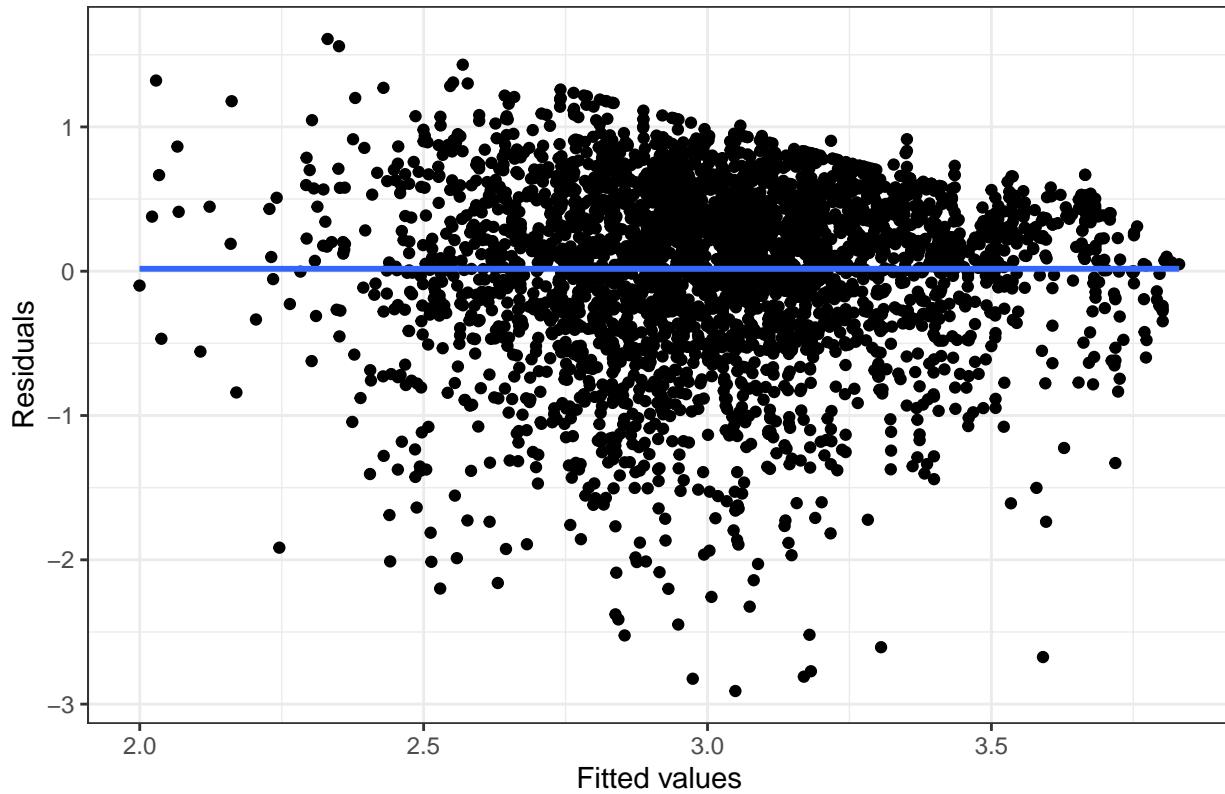
```

fm.fitted.mix.2 <- fitted(fm.splines.mix.2$lme)
fm.resid.mix.2 <- resid(fm.splines.mix.2$lme)
fm.df.mix.2 <- data.frame(fm.fitted.mix.2, fm.resid.mix.2)
fm.ggplot.mix.2 <- ggplot(fm.df.mix.2, aes(x = fm.fitted.mix.2, y = fm.resid.mix.2)) +
  geom_point() +
  geom_smooth() +
  labs(title = "Residuals vs Fitted values Spline mix (fm)", x = "Fitted values", y = "Residuals") +
  theme_bw()
fm.ggplot.mix.2

## `geom_smooth()` using method = 'gam' and formula = 'y ~ s(x, bs = "cs")'

```

Residuals vs Fitted values Spline mix (fm)



```
AIC(fm.splines.ni, fm.splines.1, fm.splines.mix, fm.splines.mix.2)
```

```
##                df      AIC
## fm.splines.ni    18 5310.356
## fm.splines.1    20 5311.898
## fm.splines.mix   17 5308.963
## fm.splines.mix.2 17 5308.382
```