Association Between Time and Alcohol Offenders on Automobile-related Fatalities and Injuries.

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Executive Summary

Negative binomial regression is used to examine the relationship between time, day and number of alcoholic offenders on the number of fatalities or injuries automobile crashes in New Zealand in 2009. Result suggests that there is association between these variables and number of alcohol offenders depend on morning time on automobile-related fatalities and injuries.

Body

Data

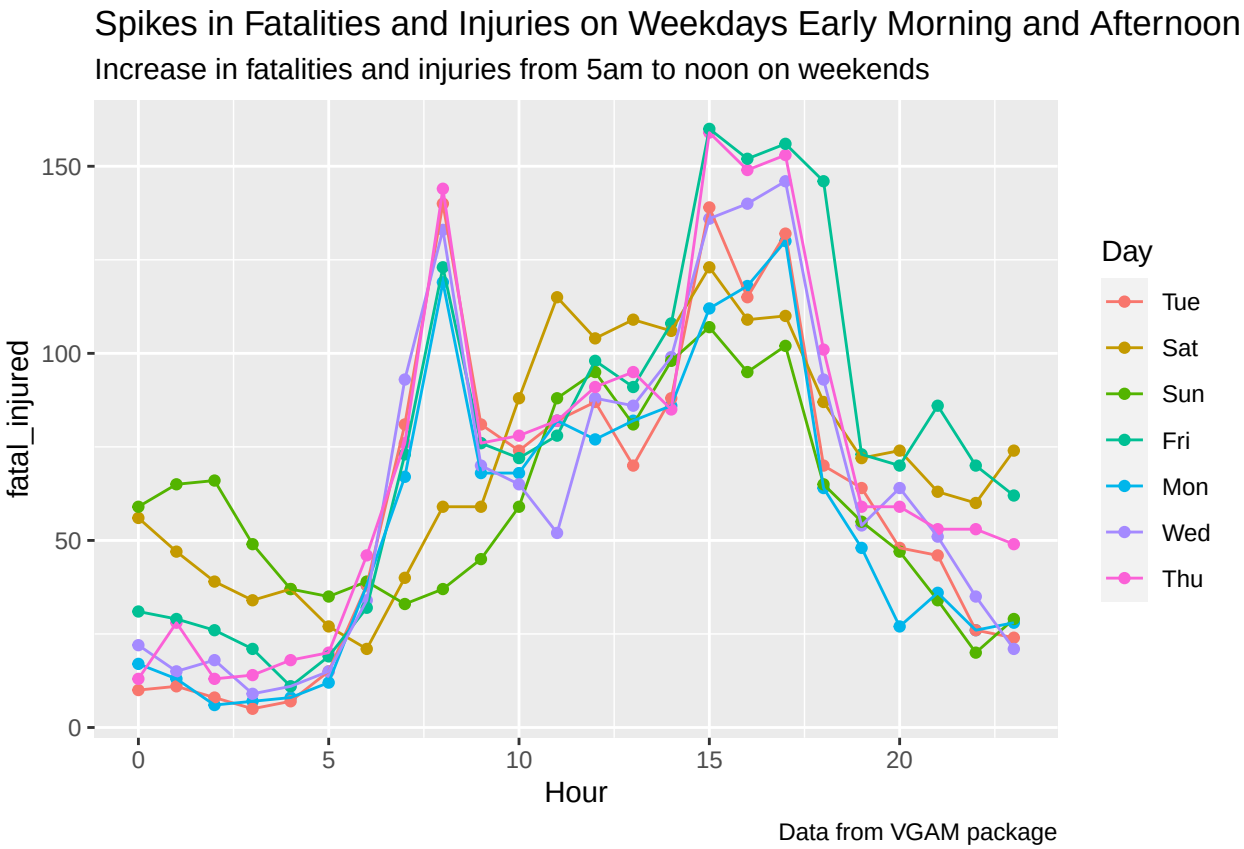
A combination of the crashi, crashf and alcoff dataset in the VGAM package constitutes the data used in the analyses of the relationship between fatalities and injuries in automobile crashes and alcohol offenders on a given day in New Zealand. The crashi, crashf and alcoff dataset consists of reported number of injuries, number of fatalities and number of alcohol offenders from breathalyzed drivers involved in crashes on New Zealand roads in 2009, respectively. The rows of the initial data represents the hourly times on a 24-hour clock starting at midnight and the columns represent the seven days of the week. The data description and design suggests that that the assumption of independence is met.

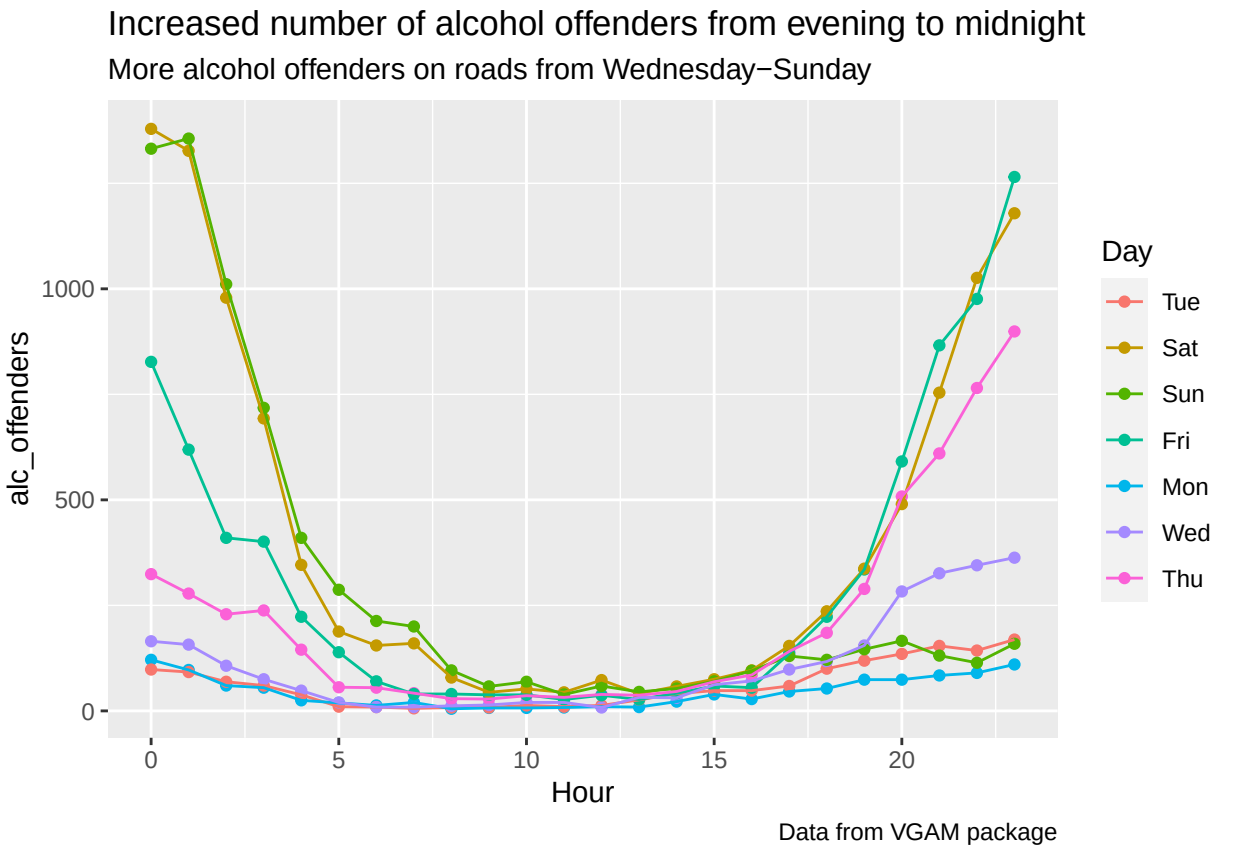
Questions of Interest

Consider the following questions: Are the number of fatalities and injures by automobile crashes related to the number of alcoholic offenders on a given day or time? Are there interactions between the time or day and the number of alcoholic offenders on the number of fatalities or injuries by car?

Analysis

In this analysis, the response variable is the combined number of fatalities and injuries by automobile crashes. Since the response variable is composed of unbounded non-zero counts with evidence of over-dispersion unaccounted by poisson model, negative binomial regression model is a more appropriate method of analysis. Exploration of the data suggest that the number of fatalities and crashes on weekdays differs from weekends in certain period of time. Time is grouped into early morning, morning, afternoon and evening with weekdays, Friday, Saturday and Sunday. To answer the questions of interest, negative binomial regression model is utilized to model the number of fatalities and injuries with explanatory variables time, day and number of alcoholic offenders. A series of drop in deviance test is performed to analysis the relationship between day, time, and the number of alcoholic offenders and their interactions(pg.12 and 13 in appendix).

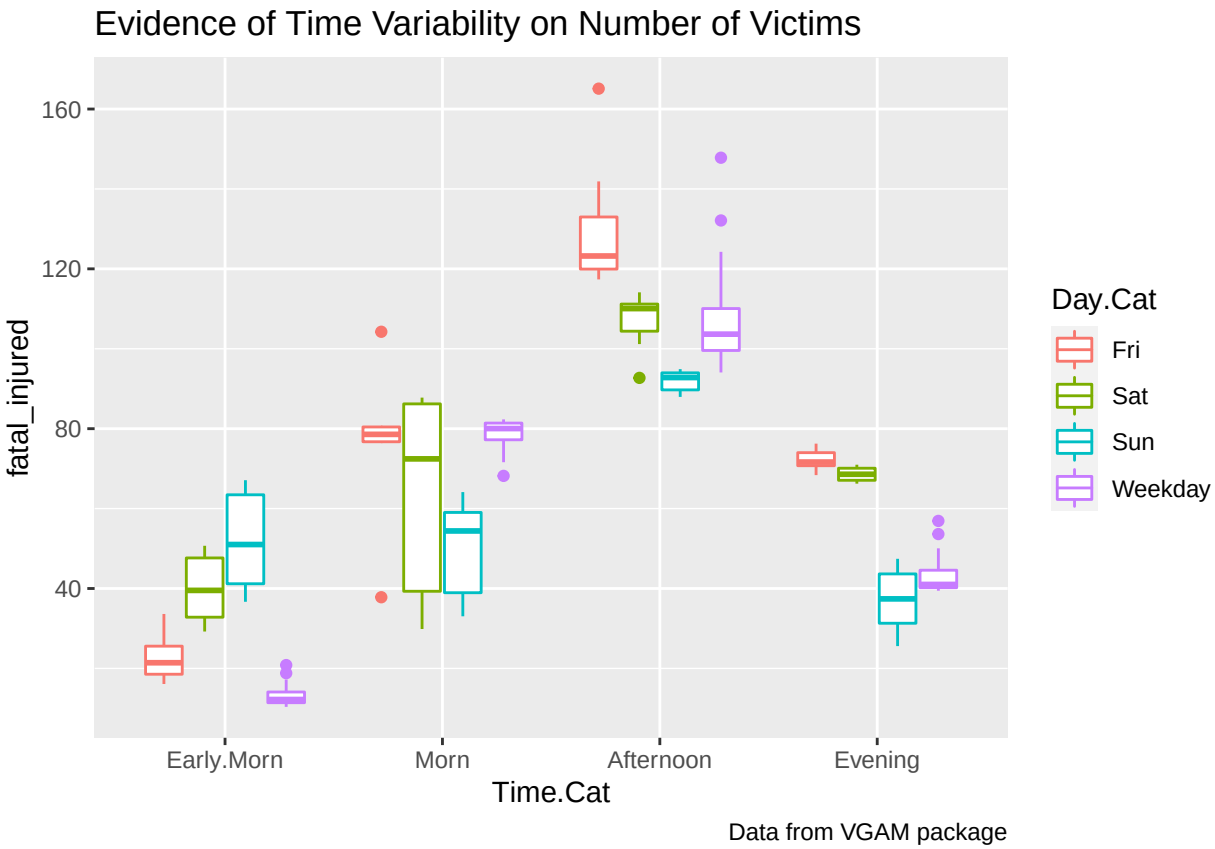

Spikes in Fatalities and Injuries on Weekdays Early Morning and Afternoon
Increase in fatalities and injuries from 5am to noon on weekends
fatal_injured
150
100
50
0
0
5
10
15
20
Hour
Data from VGAM package
Day
Tue
Sat
Sun
Fri
Mon
Wed
Thu



Result

Comparison of the rich and reduced model without interactions suggests that the rich model is a more appropriate fit(Drop in Deviance Test, p-value = 7.206e-11). Residual plots does not indicate any violations from assumption of independence and linearity(pg.14-16 in appendix). The result suggest that all three variable are associated with the number of fatalities and injuries involved in automobile crashes(table below).There is convincing evidence that the number of fatalities and injuries by automobile crashes is positively associated with time of crash on New Zealand roads in 2009(table below). There is moderate evidence that Sunday is positively associated with the number of fatalities and injuries in car-related crashes. The number of alcohol offenders is somewhat positively associated with the number of fatalities and injuries in car-related crashes in New Zealand in 2009(table below). To understand if association between the number of fatalities and injuries and time or day of crash depends on the number of alcohol offenders, two way interactions between time, day and alcohol offenders variables is examined. There is convincing evidence that the number of alcohol offenders is negatively correlated with morning time on the number of fatalities and injuries in automobile crashes(p-value = 0.00271).

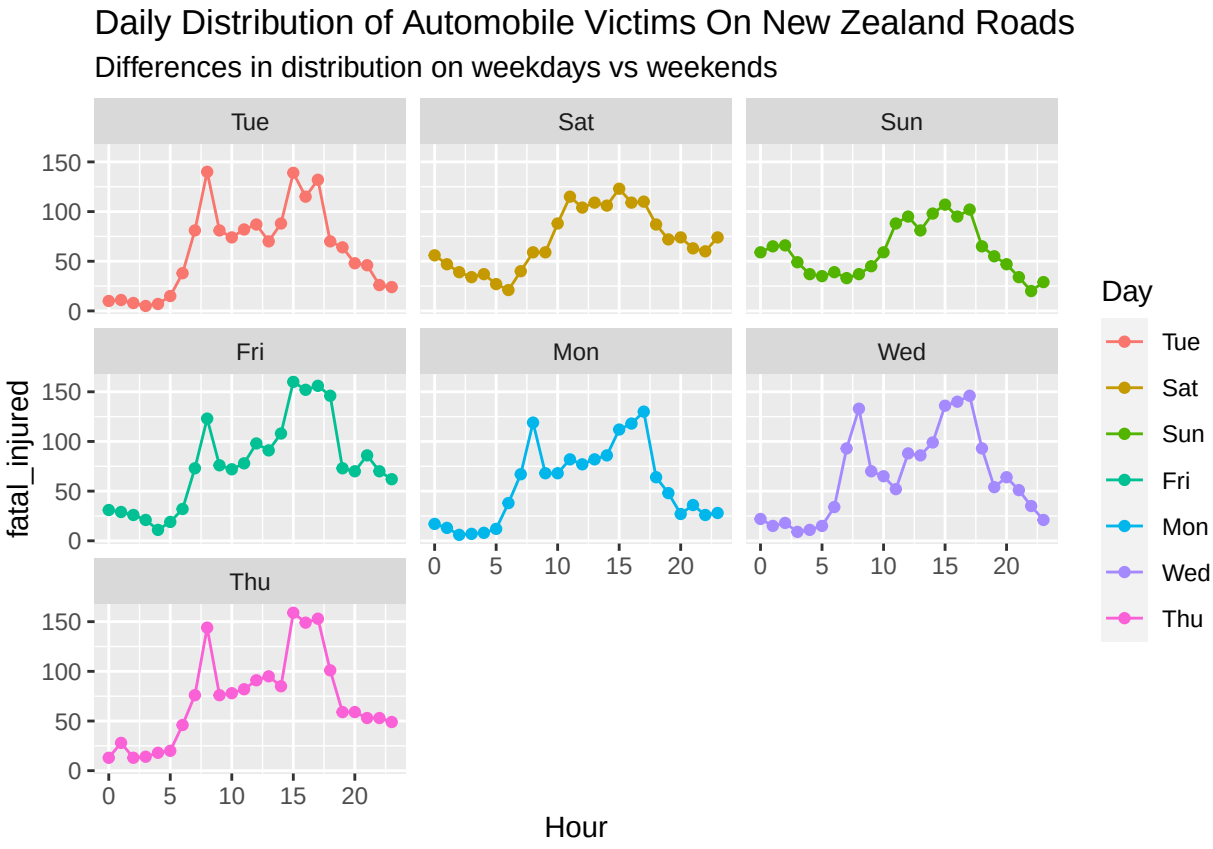
	Estimate	P-value
Sunday	0.809	0.030
Morning	2.653	3.26e-09
Afternoon	2.088	2.18e-11
Evening	1.743	2.14e-05
Alcohol offenders	0.001	0.044
Morning:Alcohol offenders	-0.025	0.003

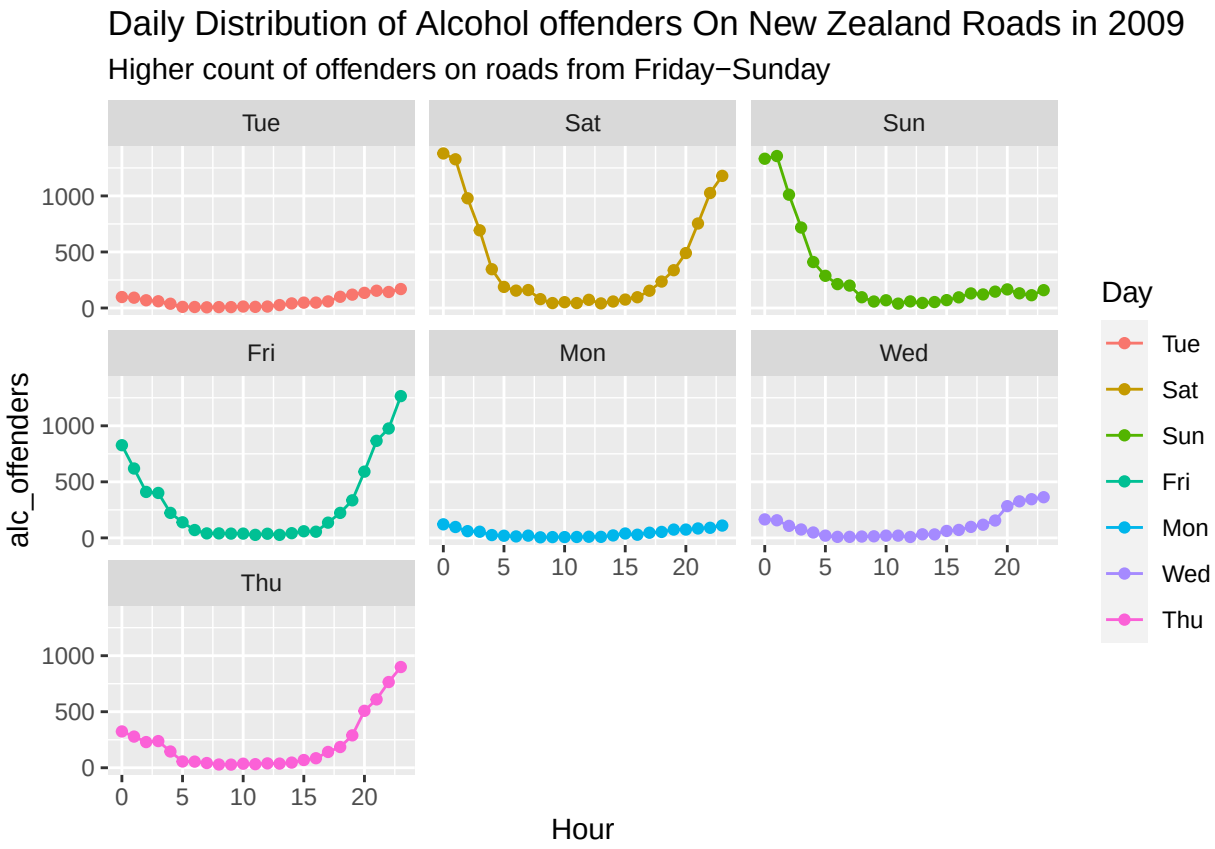


Conclusion

This study aims to find the relationship between time, day and number of alcoholic offenders on the number of fatalities and injuries in automobile crashes and determine if there is any interaction between these variables. Using negative binomial model, there is evidence of positive association between these variables and the number of fatalities and injuries. Although there is strong evidence of association between the number of alcohol offenders and automobile fatalities and injuries, it is a relatively small positive relationship. The number of fatalities and injuries in car-related crashes depend on both morning time and number of alcohol offenders. Since the distributions of car-related fatalities and injuries show the same trend, further studies can determine if grouping Friday, Saturday and Sunday together leads to different results.

Appendix


Daily Distribution of Automobile Victims On New Zealand Roads
Differences in distribution on weekdays vs weekends
Tue
Sat
Sun
Fri
Mon
Wed
Thu
fatal_injured
Hour
Day
Tue
Sat
Sun
Fri
Mon
Wed
Thu




```
# fitting a rich poisson model with interactions
# Evidence of overdispersion(763.05/144 > 1)
rich_pos <- glm(fatal_injured ~ Day.Cat * Time.Cat * alc_offenders, data = crashf2,
                family = "poisson")
summary(rich_pos)
```

```
##
## Call:
## glm(formula = fatal_injured ~ Day.Cat * Time.Cat * alc_offenders,
##     family = "poisson", data = crashf2)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -5.9130  -1.3061  -0.1674   1.0524   7.0175
##
## Coefficients:
##                                              Estimate Std. Error z value
## (Intercept)                                 2.6419622  0.1966455  13.435
## Day.CatSat                                  0.6400055  0.2462291   2.599
## Day.CatSun                                  0.8173399  0.2435798   3.356
## Day.CatWeekday                             -0.3185138  0.2184070  -1.458
## Time.CatMorn                                2.4971331  0.2624229   9.516
## Time.CatAfternoon                           2.0879604  0.2038799  10.241
## Time.CatEvening                             1.7270112  0.2419316   7.138
## alc_offenders                               0.0010451  0.0003581   2.919
## Day.CatSat:Time.CatMorn                    -0.8854412  0.3182921  -2.782
```

```
## Day.CatSun:Time.CatMorn                          -1.6171158  0.3173677  -5.095
## Day.CatWeekday:Time.CatMorn                      -0.3936344  0.2817957  -1.397
## Day.CatSat:Time.CatAfternoon                     -0.5926444  0.2617985  -2.264
## Day.CatSun:Time.CatAfternoon                     -0.9557073  0.2725648  -3.506
## Day.CatWeekday:Time.CatAfternoon                  0.1294572  0.2270819   0.570
## Day.CatSat:Time.CatEvening                       -0.7170403  0.3159509  -2.269
## Day.CatSun:Time.CatEvening                       -3.1506774  0.6670900  -4.723
## Day.CatWeekday:Time.CatEvening                   -0.4037710  0.2655060  -1.521
## Day.CatSat:alc_offenders                         -0.0005755  0.0003867  -1.488
## Day.CatSun:alc_offenders                         -0.0005015  0.0003844  -1.305
## Day.CatWeekday:alc_offenders                      0.0011222  0.0007117   1.577
## Time.CatMorn:alc_offenders                       -0.0210598  0.0042800  -4.920
## Time.CatAfternoon:alc_offenders                   0.0005605  0.0005910   0.948
## Time.CatEvening:alc_offenders                    -0.0011569  0.0003940  -2.936
## Day.CatSat:Time.CatMorn:alc_offenders             0.0111688  0.0044686   2.499
## Day.CatSun:Time.CatMorn:alc_offenders             0.0164158  0.0043831   3.745
## Day.CatWeekday:Time.CatMorn:alc_offenders         0.0152746  0.0047035   3.248
## Day.CatSat:Time.CatAfternoon:alc_offenders       -0.0020601  0.0008559  -2.407
## Day.CatSun:Time.CatAfternoon:alc_offenders       -0.0019800  0.0014037  -1.411
## Day.CatWeekday:Time.CatAfternoon:alc_offenders -0.0004728  0.0009510  -0.497
## Day.CatSat:Time.CatEvening:alc_offenders          0.0006027  0.0004537   1.328
## Day.CatSun:Time.CatEvening:alc_offenders          0.0114713  0.0041080   2.792
## Day.CatWeekday:Time.CatEvening:alc_offenders     -0.0005819  0.0007430  -0.783
##                                                 Pr(>|z|)
## (Intercept)                                      < 2e-16 ***
## Day.CatSat                                      0.009343 **
## Day.CatSun                                      0.000792 ***
## Day.CatWeekday                                  0.144744
## Time.CatMorn                                     < 2e-16 ***
## Time.CatAfternoon                                < 2e-16 ***
## Time.CatEvening                                 9.44e-13 ***
## alc_offenders                                   0.003516 **
## Day.CatSat:Time.CatMorn                         0.005405 **
## Day.CatSun:Time.CatMorn                         3.48e-07 ***
## Day.CatWeekday:Time.CatMorn                     0.162450
## Day.CatSat:Time.CatAfternoon                    0.023590 *
## Day.CatSun:Time.CatAfternoon                    0.000454 ***
## Day.CatWeekday:Time.CatAfternoon                0.568617
## Day.CatSat:Time.CatEvening                      0.023240 *
## Day.CatSun:Time.CatEvening                      2.32e-06 ***
## Day.CatWeekday:Time.CatEvening                  0.128320
## Day.CatSat:alc_offenders                        0.136729
## Day.CatSun:alc_offenders                        0.192045
## Day.CatWeekday:alc_offenders                    0.114835
## Time.CatMorn:alc_offenders                      8.63e-07 ***
## Time.CatAfternoon:alc_offenders                 0.342967
## Time.CatEvening:alc_offenders                   0.003324 **
## Day.CatSat:Time.CatMorn:alc_offenders           0.012441 *
## Day.CatSun:Time.CatMorn:alc_offenders           0.000180 ***
## Day.CatWeekday:Time.CatMorn:alc_offenders       0.001164 **
## Day.CatSat:Time.CatAfternoon:alc_offenders      0.016093 *
## Day.CatSun:Time.CatAfternoon:alc_offenders      0.158373
## Day.CatWeekday:Time.CatAfternoon:alc_offenders 0.619050
## Day.CatSat:Time.CatEvening:alc_offenders        0.184040
```

```
## Day.CatSun:Time.CatEvening:alc_offenders       0.005232 **
## Day.CatWeekday:Time.CatEvening:alc_offenders   0.433512
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 4248.75  on 167  degrees of freedom
## Residual deviance:  702.32  on 136  degrees of freedom
## AIC: 1737.9
##
## Number of Fisher Scoring iterations: 4
```

```
# fitting the reduced poisson model with no interactions
pos_mod <- glm(fatal_injured ~ Day.Cat + Time.Cat + alc_offenders, data = crashf2,
    family = "poisson")
summary(pos_mod)
```

```
##
## Call:
## glm(formula = fatal_injured ~ Day.Cat + Time.Cat + alc_offenders,
##     family = "poisson", data = crashf2)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -7.5295  -1.8805  -0.2928   1.3372   7.4934
##
## Coefficients:
##                     Estimate Std. Error z value Pr(>|z|)
## (Intercept)        2.935e+00  4.682e-02  62.690  < 2e-16 ***
## Day.CatSat        -1.295e-01  3.363e-02  -3.852 0.000117 ***
## Day.CatSun        -2.234e-01  3.521e-02  -6.345 2.22e-10 ***
## Day.CatWeekday    -9.335e-02  2.747e-02  -3.398 0.000679 ***
## Time.CatMorn       1.408e+00  4.222e-02  33.355  < 2e-16 ***
## Time.CatAfternoon  1.792e+00  3.984e-02  44.988  < 2e-16 ***
## Time.CatEvening    7.122e-01  3.967e-02  17.951  < 2e-16 ***
## alc_offenders      7.965e-04  4.746e-05  16.783  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for poisson family taken to be 1)
##
##     Null deviance: 4248.7  on 167  degrees of freedom
## Residual deviance: 1142.3  on 160  degrees of freedom
## AIC: 2129.9
##
## Number of Fisher Scoring iterations: 4
```

```
# fitting full negative binomial regression with interactions
rich_nb_mod <- glm.nb(fatal_injured ~ Day.Cat * Time.Cat * alc_offenders, data = crashf2)
summary(rich_nb_mod)
```

```
##
```

```
## Call:
## glm.nb(formula = fatal_injured ~ Day.Cat * Time.Cat * alc_offenders,
##     data = crashf2, init.theta = 20.49767466, link = log)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.9621  -0.6474  -0.1467   0.5958   2.9803
##
## Coefficients:
##                                                  Estimate Std. Error z value
## (Intercept)                                     2.6301555  0.2767035   9.505
## Day.CatSat                                      0.6584260  0.3650573   1.804
## Day.CatSun                                      0.8098703  0.3738999   2.166
## Day.CatWeekday                                 -0.3128269  0.3018160  -1.036
## Time.CatMorn                                    2.6535175  0.4483852   5.918
## Time.CatAfternoon                               2.0880297  0.3119634   6.693
## Time.CatEvening                                 1.7432191  0.4101923   4.250
## alc_offenders                                   0.0010704  0.0005321   2.012
## Day.CatSat:Time.CatMorn                        -1.0583109  0.5500285  -1.924
## Day.CatSun:Time.CatMorn                        -1.7841383  0.5528088  -3.227
## Day.CatWeekday:Time.CatMorn                    -0.5412932  0.4721227  -1.147
## Day.CatSat:Time.CatAfternoon                   -0.5956923  0.4303578  -1.384
## Day.CatSun:Time.CatAfternoon                   -0.9349917  0.4765775  -1.962
## Day.CatWeekday:Time.CatAfternoon                0.1182871  0.3432675   0.345
## Day.CatSat:Time.CatEvening                     -0.7417189  0.5569721  -1.332
## Day.CatSun:Time.CatEvening                     -3.2948488  1.0868684  -3.032
## Day.CatWeekday:Time.CatEvening                 -0.4186493  0.4379495  -0.956
## Day.CatSat:alc_offenders                       -0.0006084  0.0005867  -1.037
## Day.CatSun:alc_offenders                       -0.0005054  0.0005914  -0.854
## Day.CatWeekday:alc_offenders                    0.0011495  0.0009776   1.176
## Time.CatMorn:alc_offenders                     -0.0246562  0.0082205  -2.999
## Time.CatAfternoon:alc_offenders                 0.0006712  0.0014465   0.464
## Time.CatEvening:alc_offenders                  -0.0011877  0.0006368  -1.865
## Day.CatSat:Time.CatMorn:alc_offenders           0.0148985  0.0085188   1.749
## Day.CatSun:Time.CatMorn:alc_offenders           0.0202812  0.0083807   2.420
## Day.CatWeekday:Time.CatMorn:alc_offenders       0.0186670  0.0091665   2.036
## Day.CatSat:Time.CatAfternoon:alc_offenders     -0.0021985  0.0020658  -1.064
## Day.CatSun:Time.CatAfternoon:alc_offenders     -0.0021306  0.0032948  -0.647
## Day.CatWeekday:Time.CatAfternoon:alc_offenders -0.0003380  0.0019972  -0.169
## Day.CatSat:Time.CatEvening:alc_offenders        0.0006436  0.0007706   0.835
## Day.CatSun:Time.CatEvening:alc_offenders        0.0124956  0.0067141   1.861
## Day.CatWeekday:Time.CatEvening:alc_offenders   -0.0005876  0.0010685  -0.550
##                                                Pr(>|z|)
## (Intercept)                                     < 2e-16 ***
## Day.CatSat                                      0.07129 .
## Day.CatSun                                      0.03031 *
## Day.CatWeekday                                  0.29998
## Time.CatMorn                                   3.26e-09 ***
## Time.CatAfternoon                              2.18e-11 ***
## Time.CatEvening                                2.14e-05 ***
## alc_offenders                                   0.04423 *
## Day.CatSat:Time.CatMorn                         0.05434 .
## Day.CatSun:Time.CatMorn                         0.00125 **
## Day.CatWeekday:Time.CatMorn                     0.25158
```

```
## Day.CatSat:Time.CatAfternoon                    0.16630
## Day.CatSun:Time.CatAfternoon                    0.04978 *
## Day.CatWeekday:Time.CatAfternoon                0.73040
## Day.CatSat:Time.CatEvening                      0.18296
## Day.CatSun:Time.CatEvening                      0.00243 **
## Day.CatWeekday:Time.CatEvening                  0.33911
## Day.CatSat:alc_offenders                        0.29970
## Day.CatSun:alc_offenders                        0.39285
## Day.CatWeekday:alc_offenders                    0.23968
## Time.CatMorn:alc_offenders                      0.00271 **
## Time.CatAfternoon:alc_offenders                 0.64264
## Time.CatEvening:alc_offenders                   0.06218 .
## Day.CatSat:Time.CatMorn:alc_offenders           0.08031 .
## Day.CatSun:Time.CatMorn:alc_offenders           0.01552 *
## Day.CatWeekday:Time.CatMorn:alc_offenders       0.04171 *
## Day.CatSat:Time.CatAfternoon:alc_offenders      0.28722
## Day.CatSun:Time.CatAfternoon:alc_offenders      0.51785
## Day.CatWeekday:Time.CatAfternoon:alc_offenders  0.86561
## Day.CatSat:Time.CatEvening:alc_offenders        0.40360
## Day.CatSun:Time.CatEvening:alc_offenders        0.06273 .
## Day.CatWeekday:Time.CatEvening:alc_offenders    0.58235
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(20.4977) family taken to be 1)
##
##     Null deviance: 1155.71  on 167  degrees of freedom
## Residual deviance:  168.45  on 136  degrees of freedom
## AIC: 1429.1
##
## Number of Fisher Scoring iterations: 1
##
##
##               Theta:  20.50
##           Std. Err.:  3.09
##
##  2 x log-likelihood:  -1363.134
```

```
# fitting negative binomial regression without interactions
nb_mod <-  glm.nb(fatal_injured ~ Day.Cat + Time.Cat + alc_offenders, data = crashf2)
summary(nb_mod)
```

```
##
## Call:
## glm.nb(formula = fatal_injured ~ Day.Cat + Time.Cat + alc_offenders,
##     data = crashf2, init.theta = 9.95021461, link = log)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -3.1698  -0.7295  -0.1155   0.5339   2.4148
##
## Coefficients:
##                     Estimate Std. Error z value Pr(>|z|)
## (Intercept)        2.7823503  0.1054443  26.387  < 2e-16 ***
```

```
## Day.CatSat        -0.0687782  0.0996077  -0.690    0.490
## Day.CatSun        -0.1089177  0.0995319  -1.094    0.274
## Day.CatWeekday    -0.0885146  0.0820162  -1.079    0.280
## Time.CatMorn       1.5363295  0.0894238  17.180  < 2e-16 ***
## Time.CatAfternoon  1.9059180  0.0853001  22.344  < 2e-16 ***
## Time.CatEvening    0.8079947  0.0839134   9.629  < 2e-16 ***
## alc_offenders      0.0009423  0.0001169   8.060 7.65e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(9.9502) family taken to be 1)
##
##     Null deviance: 667.60  on 167  degrees of freedom
## Residual deviance: 173.02  on 160  degrees of freedom
## AIC: 1478.9
##
## Number of Fisher Scoring iterations: 1
##
##
##               Theta:  9.95
##           Std. Err.:  1.31
##
##  2 x log-likelihood:  -1460.899
```

```
# Comparing rich negative binomial, negative binomial, rich poisson and poission model
LRstats(rich_nb_mod,nb_mod,rich_pos,pos_mod)
```

```
## Likelihood summary table:
##                AIC    BIC LR Chisq  Df Pr(>Chisq)
## rich_nb_mod 1429.1 1532.2   168.45 136    0.03077 *
## nb_mod      1478.9 1507.0   173.02 160    0.22790
## rich_pos    1737.9 1837.9   702.32 136    < 2e-16 ***
## pos_mod     2129.9 2154.9  1142.31 160    < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# Drop in deviance test for negative binomial model with and without interactions.
anova(nb_mod,rich_nb_mod,test="Chisq")
```

```
## Likelihood ratio tests of Negative Binomial Models
##
## Response: fatal_injured
##                                Model     theta Resid. df    2 x log-lik.   Test
## 1 Day.Cat + Time.Cat + alc_offenders  9.950215       160       -1460.899
## 2 Day.Cat * Time.Cat * alc_offenders 20.497675       136       -1363.134 1 vs 2
##      df LR stat.      Pr(Chi)
## 1
## 2    24 97.76517 7.206147e-11
```

```
# fitting nested negative binomial regression with only Day.Cat and Time.Cat variables
nb_red_mod2 <-  glm.nb(fatal_injured ~ Day.Cat + Time.Cat, data = crashf2)
summary(nb_red_mod2)
```

```
##
## Call:
## glm.nb(formula = fatal_injured ~ Day.Cat + Time.Cat, data = crashf2,
##     init.theta = 6.818752376, link = log)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.8477  -0.7925  -0.1379   0.5132   2.7363
##
## Coefficients:
##                   Estimate Std. Error z value Pr(>|z|)
## (Intercept)        3.28273    0.10173  32.271  < 2e-16 ***
## Day.CatSat         0.03693    0.11683   0.316  0.75195
## Day.CatSun        -0.05931    0.11713  -0.506  0.61260
## Day.CatWeekday    -0.26176    0.09273  -2.823  0.00476 **
## Time.CatMorn       1.16410    0.09141  12.734  < 2e-16 ***
## Time.CatAfternoon  1.55699    0.08786  17.720  < 2e-16 ***
## Time.CatEvening    0.77325    0.09648   8.015  1.1e-15 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(6.8188) family taken to be 1)
##
##     Null deviance: 486.16  on 167  degrees of freedom
## Residual deviance: 176.76  on 161  degrees of freedom
## AIC: 1534.9
##
## Number of Fisher Scoring iterations: 1
##
##
##               Theta:  6.819
##           Std. Err.:  0.860
##
##  2 x log-likelihood:  -1518.925
```

```
# fitting nested negative binomial regression with only Day.Cat variable
nb_red_mod3 <-  glm.nb(fatal_injured ~ Day.Cat, data = crashf2)
summary(nb_red_mod3)
```

```
##
## Call:
## glm.nb(formula = fatal_injured ~ Day.Cat, data = crashf2, init.theta = 2.322909064,
##     link = log)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -2.59305  -0.90457  -0.06148   0.52574   1.63824
##
## Coefficients:
##                Estimate Std. Error z value Pr(>|z|)
## (Intercept)     4.35189    0.13592  32.018   <2e-16 ***
## Day.CatSat     -0.08394    0.19234  -0.436    0.663
## Day.CatSun     -0.25754    0.19263  -1.337    0.181
## Day.CatWeekday -0.20611    0.15206  -1.355    0.175
```

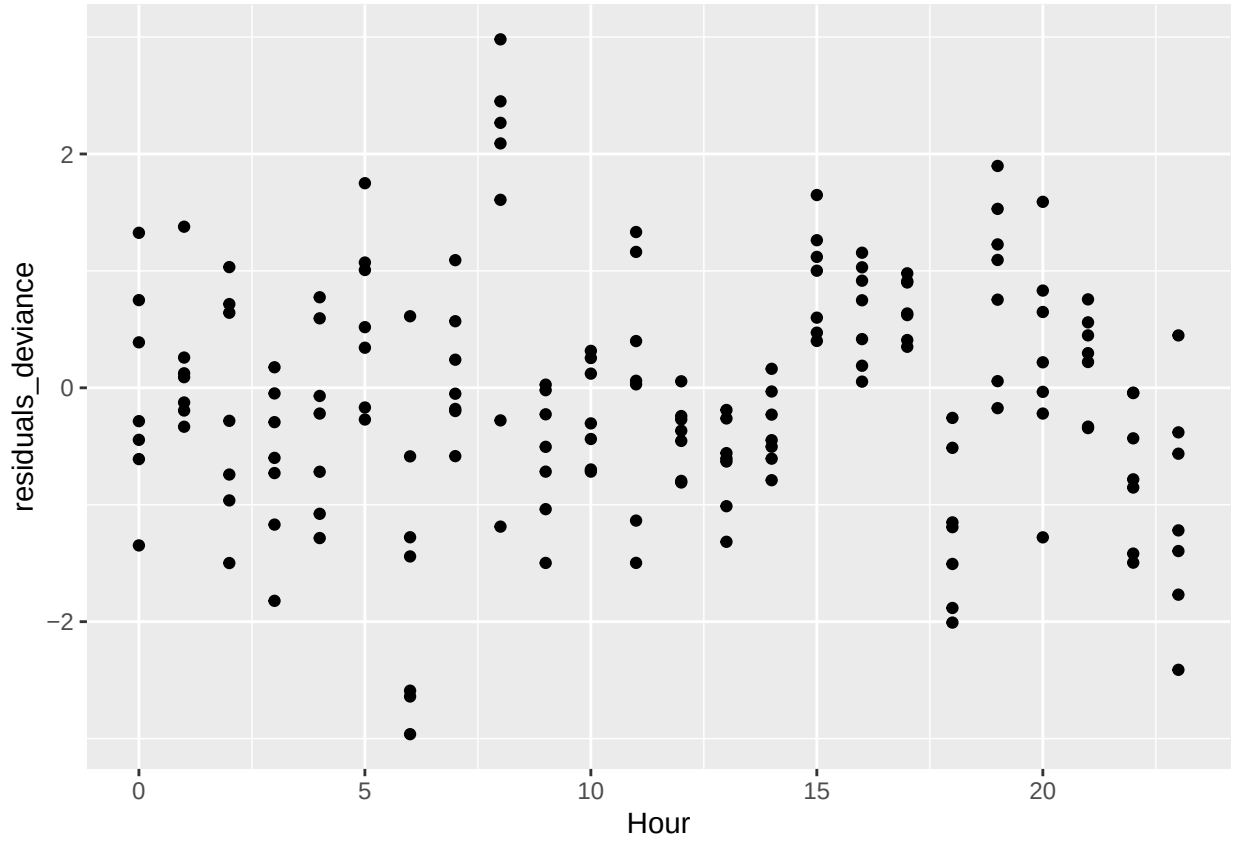
```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for Negative Binomial(2.3229) family taken to be 1)
##
##     Null deviance: 182.78  on 167  degrees of freedom
## Residual deviance: 180.05  on 164  degrees of freedom
## AIC: 1703.7
##
## Number of Fisher Scoring iterations: 1
##
##
##               Theta:  2.323
##           Std. Err.:  0.251
##
##  2 x log-likelihood:  -1693.728
```

```
# Drop in deviance test for nested model and full model without interactions.
anova(nb_red_mod2,nb_mod,test="Chisq")
```

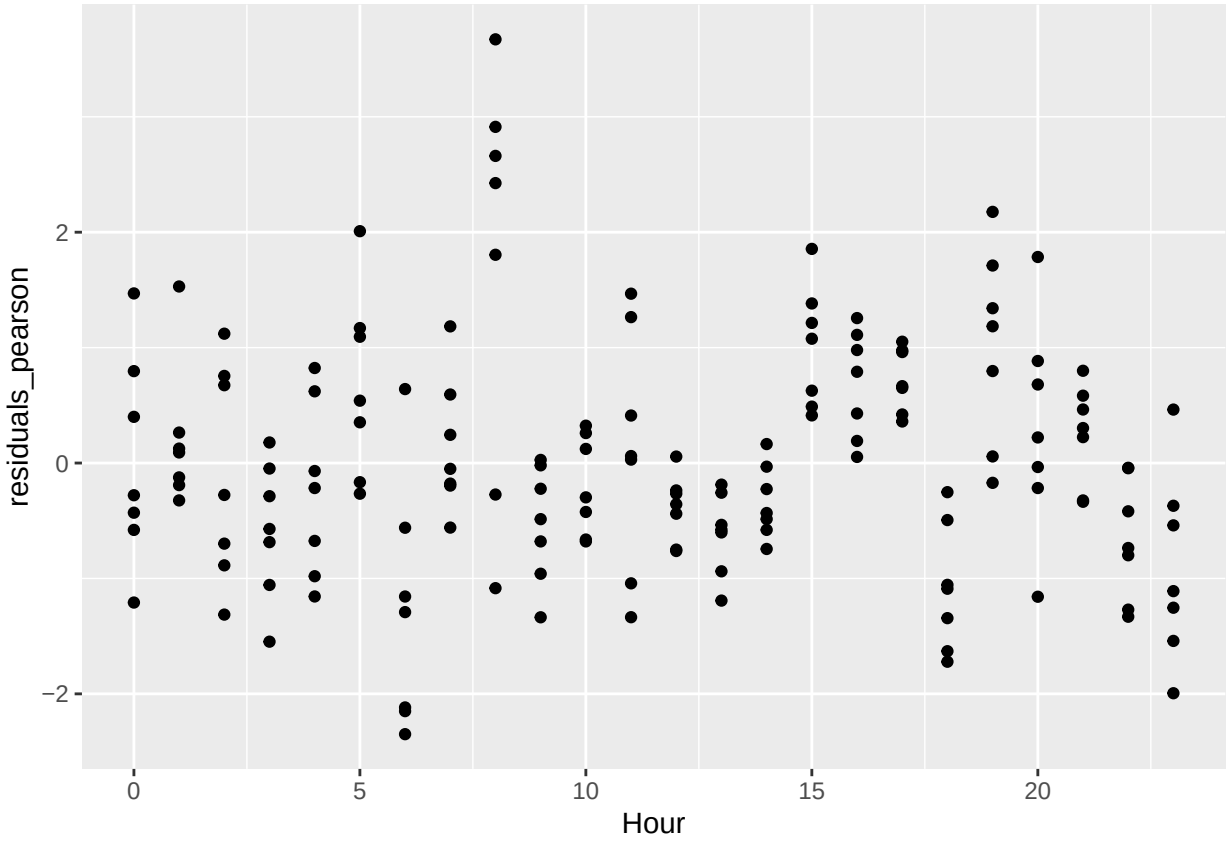
```
## Likelihood ratio tests of Negative Binomial Models
##
## Response: fatal_injured
##                                 Model    theta Resid. df    2 x log-lik.   Test
## 1                 Day.Cat + Time.Cat 6.818752       161       -1518.925
## 2 Day.Cat + Time.Cat + alc_offenders 9.950215       160       -1460.899 1 vs 2
##      df LR stat.     Pr(Chi)
## 1
## 2     1 58.02589 2.58682e-14
```

```
# Drop in deviance test for nested model and full model without interactions.
anova(nb_red_mod3,rich_nb_mod,test="Chisq")
```

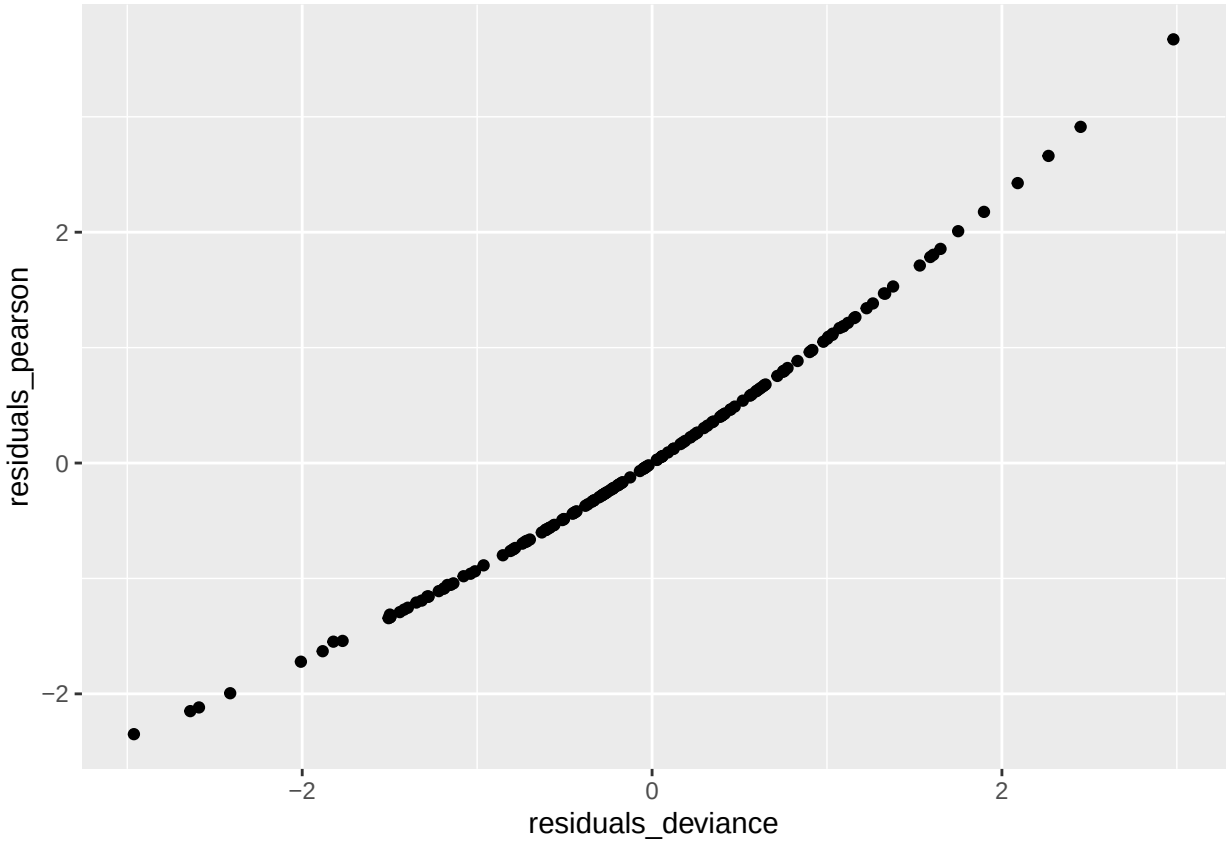
```
## Likelihood ratio tests of Negative Binomial Models
##
## Response: fatal_injured
##                                   Model     theta Resid. df    2 x log-lik.   Test
## 1                             Day.Cat  2.322909       164       -1693.728
## 2 Day.Cat * Time.Cat * alc_offenders 20.497675       136       -1363.134 1 vs 2
##      df LR stat. Pr(Chi)
## 1
## 2    28 330.5946       0
```




```
# person residual plots using full negative binomial model
ggplot(data = crashf2, aes(Hour,residuals_pearson)) + geom_point()
```




```
ggplot(data = crashf2, aes(residuals_deviance,residuals_pearson)) + geom_point()
```


residuals_pearson
2
0
−2
−2
0
2
residuals_deviance