

Sorry, really unsure about 2.1.e
 make here? I am not familiar w/ it.

$$\begin{aligned}
 2A) \operatorname{tr}(H) &= \operatorname{tr}(X(X^T X)^{-1} X^T) \\
 &= \operatorname{tr}(X^T X (X^T X)^{-1}) \\
 &= \operatorname{tr}(\underbrace{I}_{15}) \\
 &= 15
 \end{aligned}$$

$$I \times I = I$$

∴ H is idempotent

$$2B) h_{ii} = \frac{1}{n} \frac{\sum (x_i - \bar{x})^2}{\sum (x_j - \bar{x})^2}$$

$$\begin{aligned}
 E(h_{ii}) &= \frac{1}{n} \sum_i 1 & E(x_i) &= \bar{x} \\
 &= \frac{1}{n} n & E(x_j) &= \bar{x}
 \end{aligned}$$

2C) If that were true I
 it would be $e_i = \frac{e_i}{1 - 1/5}$

Ryan Richardson Quiz 1

Ryan Richardson

22/10/2020

Question 1

1a

```
summary(mpgData)
```

```
## manufacturer      model      displ      year
## Length:234      Length:234      Min.   :1.600      Min.   :1999
## Class :character Class :character 1st Qu.:2.400      1st Qu.:1999
## Mode  :character Mode  :character Median :3.300      Median :2004
##                               Mean  :3.472      Mean  :2004
##                               3rd Qu.:4.600      3rd Qu.:2008
##                               Max.   :7.000      Max.   :2008
##      cyl      trans      drv      cty
## Min.   :4.000      Length:234      Length:234      Min.   : 9.00
## 1st Qu.:4.000      Class :character Class :character 1st Qu.:14.00
## Median :6.000      Mode  :character Mode  :character Median :17.00
## Mean   :5.889                               Mean   :16.86
## 3rd Qu.:8.000                               3rd Qu.:19.00
## Max.   :8.000                               Max.   :35.00
##      hwy      fl      class
## Min.   :12.00      Length:234      Length:234
## 1st Qu.:18.00      Class :character Class :character
## Median :24.00      Mode  :character Mode  :character
## Mean   :23.44
## 3rd Qu.:27.00
## Max.   :44.00
```

```
head(mpgData)
```

```
## # A tibble: 6 x 11
##   manufacturer model displ year  cyl trans      drv      cty      hwy fl      class
##   <chr>         <chr> <dbl> <int> <int> <chr>    <chr> <int> <int> <chr> <chr>
## 1 audi         a4      1.8  1999     4 auto(l5) f         18      29 p      compa~
## 2 audi         a4      1.8  1999     4 manual(m5) f         21      29 p      compa~
## 3 audi         a4      2    2008     4 manual(m6) f         20      31 p      compa~
## 4 audi         a4      2    2008     4 auto(av) f         21      30 p      compa~
## 5 audi         a4      2.8  1999     6 auto(l5) f         16      26 p      compa~
## 6 audi         a4      2.8  1999     6 manual(m5) f         18      26 p      compa~
```

```
mpgData$manufacturer = as.factor(mpgData$manufacturer)
mpgData$model = as.factor(mpgData$model)
mpgData$cyl = as.factor(mpgData$cyl)
mpgData$drv = as.factor(mpgData$drv)
```

```
mpgData$fl = as.factor(mpgData$fl)
mpgData$class = as.factor(mpgData$class)
mpgData$trans = as.factor(mpgData$trans)

mpgData$avgMpg = (mpgData$cty + mpgData$hwy) / 2
mpgData = mpgData[, !names(mpgData) %in% c("cty", "hwy")]
```

1b

Dataset is 234 observations with, originally, 11 variables, 12 with average mpg, this then drops to 10 when we remove cty and hwy as they are directly tied to avg mpg.

```
names(mpgData)
```

```
## [1] "manufacturer" "model"          "displ"          "year"          "cyl"
## [6] "trans"         "drv"           "fl"            "class"         "avgMpg"
```

```
dim(mpgData)
```

```
## [1] 234 10
```

```
summary(mpgData)
```

```
##      manufacturer      model      displ      year
## dodge      :37   caravan 2wd      : 11   Min.   :1.600   Min.   :1999
## toyota      :34   ram 1500 pickup 4wd: 10   1st Qu.:2.400   1st Qu.:1999
## volkswagen:27   civic              : 9   Median :3.300   Median :2004
## ford        :25   dakota pickup 4wd : 9   Mean    :3.472   Mean    :2004
## chevrolet   :19   jetta                : 9   3rd Qu.:4.600   3rd Qu.:2008
## audi        :18   mustang              : 9   Max.    :7.000   Max.    :2008
## (Other)     :74   (Other)              :177

## cyl      trans  drv  fl      class      avgMpg
## 4:81   auto(l4) :83  4:103  c: 1   2seater   : 5   Min.   :10.50
## 5: 4   manual(m5):58  f:106  d: 5   compact   :47   1st Qu.:15.50
## 6:79   auto(l5) :39  r: 25  e: 8   midsize   :41   Median :20.50
## 8:70   manual(m6):19          p: 52  minivan   :11   Mean    :20.15
##          auto(s6) :16          r:168  pickup     :33   3rd Qu.:23.50
##          auto(l6) : 6          subcompact:35   Max.    :39.50
##          (Other)  :13          suv       :62
```

Question 1C

We needed to change Manufactureer, Model, Cylinders, Drive Train, Fuel Type, Car Class, and Transmission to categorical variables.

There may be an argument for converting year to a categorical variable as well, but I chose not to make this change initially to see how the model turned out

Question 1D

```
lMod = lm(avgMpg ~ ., data = mpgData)
```

```
stepMod = stepAIC(lMod, direction="both")
```

```
## Start: AIC=151.61
```

```
## avgMpg ~ manufacturer + model + displ + year + cyl + trans +
```

```

##      drv + fl + class
##
##
## Step: AIC=151.61
## avgMpg ~ manufacturer + model + displ + year + cyl + trans +
##      fl + class
##
##
## Step: AIC=151.61
## avgMpg ~ model + displ + year + cyl + trans + fl + class
##
##      Df Sum of Sq    RSS    AIC
## - trans  9      20.92 293.38 150.92
## <none>                272.46 151.61
## - class  2       6.25 278.71 152.92
## - displ  1       8.13 280.59 156.49
## - cyl    3      52.23 324.69 186.65
## - year   1      49.78 322.24 188.87
## - model 33     316.29 588.75 265.91
## - fl     4     406.10 678.56 357.13
##
## Step: AIC=150.92
## avgMpg ~ model + displ + year + cyl + fl + class
##
##      Df Sum of Sq    RSS    AIC
## - class  2       4.56 297.94 150.52
## <none>                293.38 150.92
## + trans  9      20.92 272.46 151.61
## - displ  1       7.83 301.20 155.08
## - cyl    3      52.33 345.71 183.33
## - year   1      74.92 368.30 202.14
## - model 33     322.82 616.20 258.57
## - fl     4     416.71 710.08 349.75
##
## Step: AIC=150.52
## avgMpg ~ model + displ + year + cyl + fl
##
##      Df Sum of Sq    RSS    AIC
## <none>                297.94 150.52
## + class  2       4.56 293.38 150.92
## + trans  9      19.22 278.71 152.92
## - displ  1       7.97 305.90 154.70
## - cyl    3      49.91 347.85 180.77
## - year   1      81.81 379.75 205.30
## - fl     4     416.53 714.47 347.20
## - model 37    1138.13 1436.07 444.56

```

```

summary(stepMod)

```

```

##
## Call:
## lm(formula = avgMpg ~ model + displ + year + cyl + fl, data = mpgData)
##
## Residuals:
##      Min       1Q   Median       3Q      Max

```

```

## -5.8909 -0.4819 0.0041 0.4847 5.1745
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -275.61764    41.46160   -6.648 3.17e-10 ***
## modela4         6.32612     0.84857    7.455 3.25e-12 ***
## modela4 quattro  4.30888     0.82646    5.214 4.88e-07 ***
## modela6 quattro  4.49662     0.99395    4.524 1.08e-05 ***
## modelaltima     6.40118     0.75425    8.487 6.41e-15 ***
## modelc1500 suburban 2wd  1.09289     0.86699    1.261 0.209041
## modelcamry      5.80305     0.72073    8.052 9.28e-14 ***
## modelcamry solara  5.71142     0.72247    7.905 2.25e-13 ***
## modelcaravan 2wd  2.65919     0.64971    4.093 6.33e-05 ***
## modelcivic      8.88164     0.79026   11.239 < 2e-16 ***
## modelcorolla    10.09008     0.83963   12.017 < 2e-16 ***
## modelcorvette    7.01040     0.95263    7.359 5.69e-12 ***
## modeldakota pickup 4wd  -0.39444     0.68939   -0.572 0.567899
## modeldurango 4wd  -0.68398     0.76171   -0.898 0.370363
## modelexpedition 2wd  -0.39173     0.95197   -0.411 0.681179
## modelexplorer 4wd    0.14616     0.74291    0.197 0.844246
## modelf150 pickup 4wd  -0.39319     0.74077   -0.531 0.596201
## modelforester awd    2.76748     0.77124    3.588 0.000425 ***
## modelgrand cherokee 4wd -0.66019     0.72051   -0.916 0.360699
## modelgrand prix    6.14328     0.78121    7.864 2.88e-13 ***
## modelgti         5.15383     0.83198    6.195 3.63e-09 ***
## modelimpreza awd    3.72743     0.72346    5.152 6.50e-07 ***
## modeljetta       5.92186     0.75563    7.837 3.39e-13 ***
## modelk1500 tahoe 4wd  -1.18790     0.96032   -1.237 0.217642
## modelland cruiser wagon 4wd -0.65053     1.08402   -0.600 0.549159
## modelmalibu      5.28038     0.77336    6.828 1.17e-10 ***
## modelmaxima      5.78213     0.92087    6.279 2.32e-09 ***
## modelmountaineer 4wd  -0.10320     0.83119   -0.124 0.901322
## modelmustang      3.90715     0.68566    5.698 4.64e-08 ***
## modelnavigator 2wd    0.05205     0.96562    0.054 0.957071
## modelnew beetle    6.81752     0.87045    7.832 3.48e-13 ***
## modelpassat      5.87663     0.84042    6.992 4.64e-11 ***
## modelpathfinder 4wd    0.40110     0.83628    0.480 0.632052
## modelram 1500 pickup 4wd  -1.07716     0.72940   -1.477 0.141414
## modelrange rover  -0.90428     0.89343   -1.012 0.312781
## modelsonata      5.00794     0.72836    6.876 8.96e-11 ***
## modeltiburon     3.23016     0.75843    4.259 3.25e-05 ***
## modeltoyota tacoma 4wd  -0.05623     0.70561   -0.080 0.936565
## displ          -0.70724     0.31627   -2.236 0.026520 *
## year           0.14841     0.02071    7.166 1.73e-11 ***
## cyl5          -1.76096     0.80649   -2.183 0.030245 *
## cyl6          -2.01458     0.39333   -5.122 7.49e-07 ***
## cyl8          -2.53833     0.76822   -3.304 0.001142 **
## fld           7.79600     1.50609    5.176 5.81e-07 ***
## fle          -4.94608     1.43747   -3.441 0.000715 ***
## flp          -1.87257     1.36387   -1.373 0.171400
## flr          -0.60703     1.34836   -0.450 0.653090
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##

```

```
## Residual standard error: 1.262 on 187 degrees of freedom
## Multiple R-squared:  0.9499, Adjusted R-squared:  0.9375
## F-statistic: 77.02 on 46 and 187 DF,  p-value: < 2.2e-16
```

Question 1E

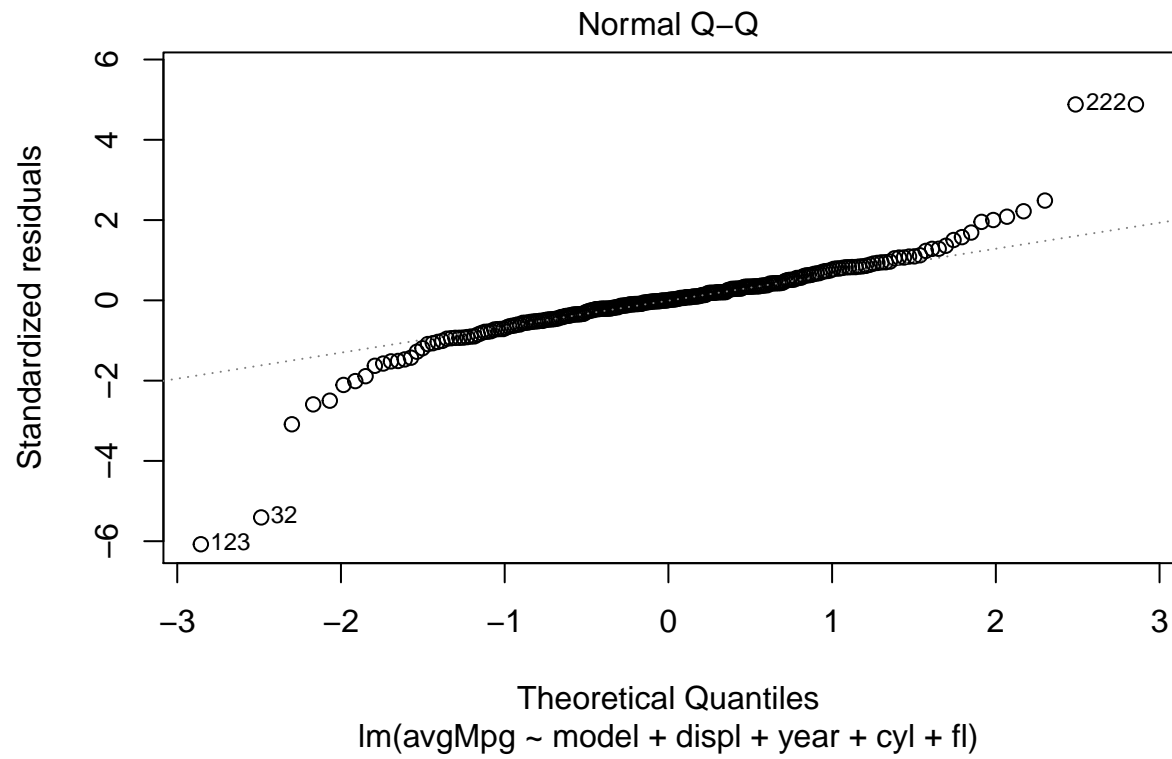
```
bestMainEffects = lm(formula = avgMpg ~ model + displ + year + cyl + fl, data = mpgData)
summary(bestMainEffects)
```

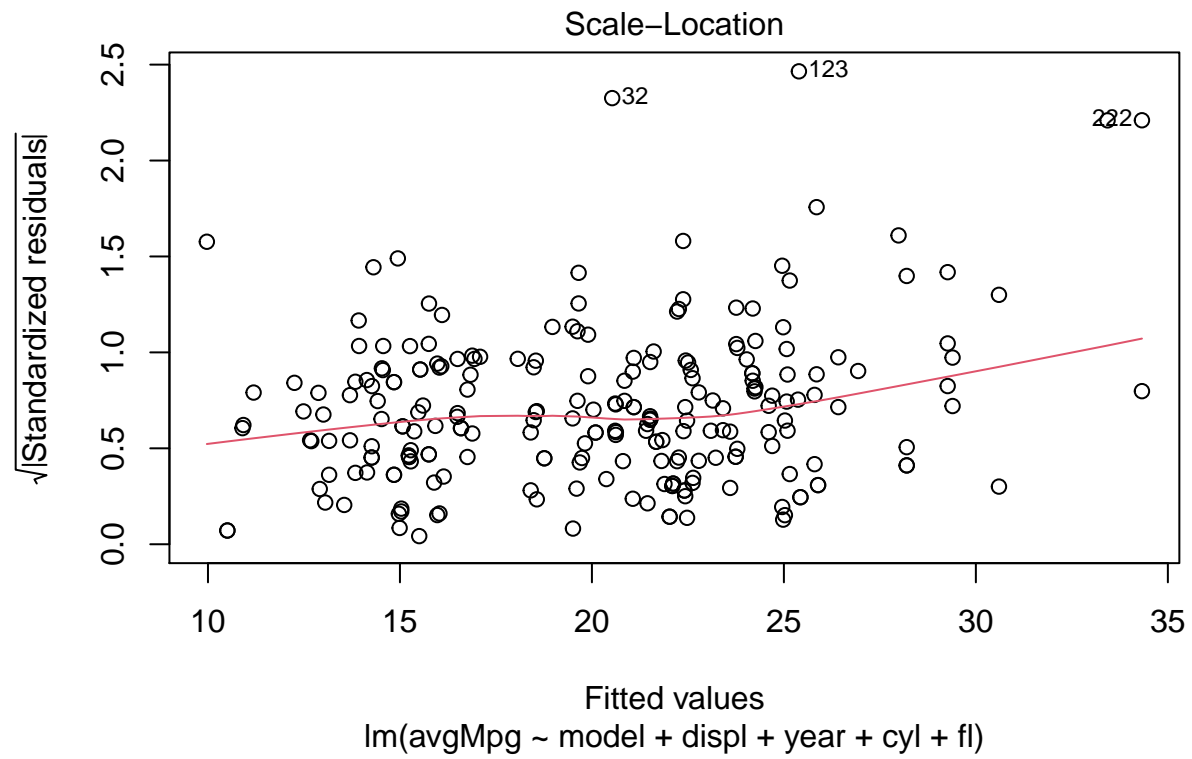
```
##
## Call:
## lm(formula = avgMpg ~ model + displ + year + cyl + fl, data = mpgData)
##
## Residuals:
```

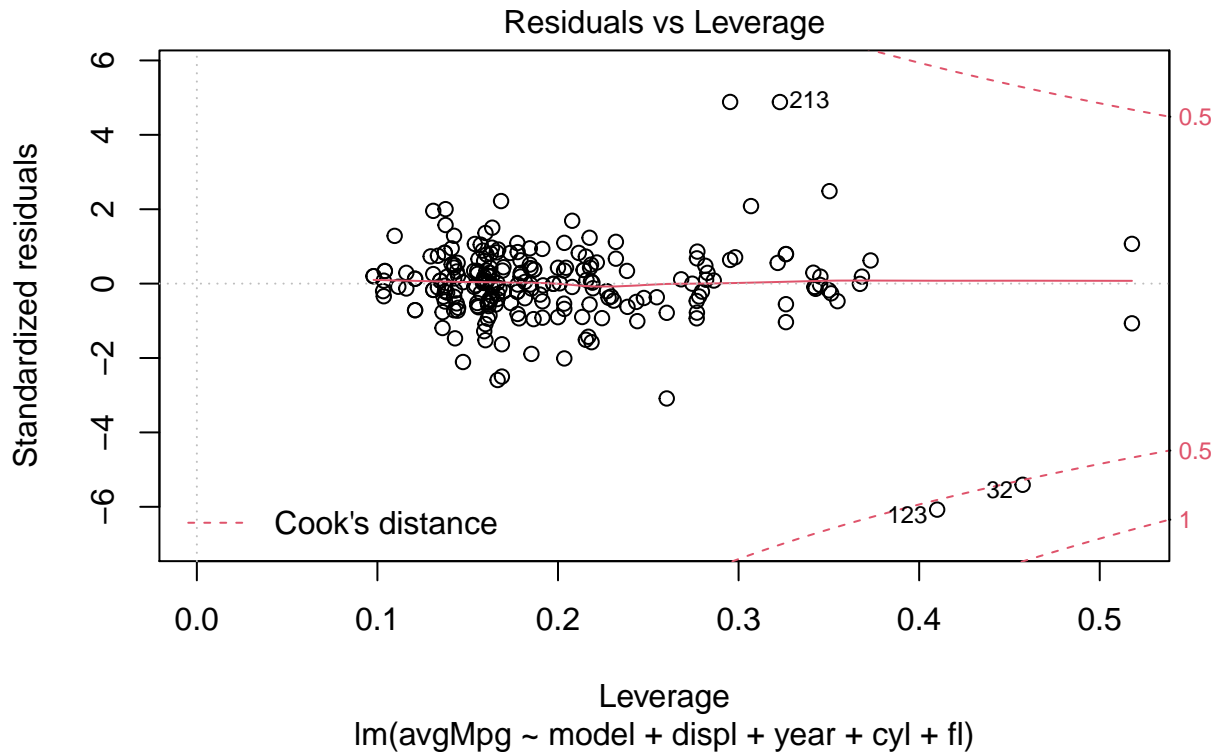
	Min	1Q	Median	3Q	Max
	-5.8909	-0.4819	0.0041	0.4847	5.1745

```
##
## Coefficients:
```

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-275.61764	41.46160	-6.648	3.17e-10 ***
modela4	6.32612	0.84857	7.455	3.25e-12 ***
modela4 quattro	4.30888	0.82646	5.214	4.88e-07 ***
modela6 quattro	4.49662	0.99395	4.524	1.08e-05 ***
modelaltima	6.40118	0.75425	8.487	6.41e-15 ***
modelc1500 suburban 2wd	1.09289	0.86699	1.261	0.209041
modelcamry	5.80305	0.72073	8.052	9.28e-14 ***
modelcamry solara	5.71142	0.72247	7.905	2.25e-13 ***
modelcaravan 2wd	2.65919	0.64971	4.093	6.33e-05 ***
modelcivic	8.88164	0.79026	11.239	< 2e-16 ***
modelcorolla	10.09008	0.83963	12.017	< 2e-16 ***
modelcorvette	7.01040	0.95263	7.359	5.69e-12 ***
modeldakota pickup 4wd	-0.39444	0.68939	-0.572	0.567899
modeldurango 4wd	-0.68398	0.76171	-0.898	0.370363
modelexpedition 2wd	-0.39173	0.95197	-0.411	0.681179
modelexplorer 4wd	0.14616	0.74291	0.197	0.844246
modelf150 pickup 4wd	-0.39319	0.74077	-0.531	0.596201
modelforester awd	2.76748	0.77124	3.588	0.000425 ***
modelgrand cherokee 4wd	-0.66019	0.72051	-0.916	0.360699
modelgrand prix	6.14328	0.78121	7.864	2.88e-13 ***
modelgti	5.15383	0.83198	6.195	3.63e-09 ***
modelimpreza awd	3.72743	0.72346	5.152	6.50e-07 ***
modeljetta	5.92186	0.75563	7.837	3.39e-13 ***
modelk1500 tahoe 4wd	-1.18790	0.96032	-1.237	0.217642
modelland cruiser wagon 4wd	-0.65053	1.08402	-0.600	0.549159
modelmalibu	5.28038	0.77336	6.828	1.17e-10 ***
modelmaxima	5.78213	0.92087	6.279	2.32e-09 ***
modelmountaineer 4wd	-0.10320	0.83119	-0.124	0.901322
modelmustang	3.90715	0.68566	5.698	4.64e-08 ***
modelnavigator 2wd	0.05205	0.96562	0.054	0.957071
modelnew beetle	6.81752	0.87045	7.832	3.48e-13 ***
modelpassat	5.87663	0.84042	6.992	4.64e-11 ***
modelpathfinder 4wd	0.40110	0.83628	0.480	0.632052
modelram 1500 pickup 4wd	-1.07716	0.72940	-1.477	0.141414
modelrange rover	-0.90428	0.89343	-1.012	0.312781







Question 1F

Looking at the initial graphs, significance of the coefficients provided by Step AIC, and adj-rsquared, the overall model appears to be a decent fit. Residuals vs Fitted is mostly linear which leads me to believe that linear regression was not a bad choice, and there is not much clustering of the data, despite the number of categorical variables introduced which tells me there is no over-powering effect caused by any one category.

The QQ plot however has tails that may suggest some of the data is not normally distributed. However, it is mostly linear, which makes me believe the heavy tails are resulting from a few outliers that are marked on the graph.

The Scale-Location graph is not really linear, despite having a relatively even spread throughout the increase. This could mean that the data is heteroskedastic, but I don't think it's extreme enough to warrant concern.

Lastly, the residuals vs leverage plot is not too concerning as all values are at or below a Cook's distance of 0.5, which should mean that the extreme values are not having too large of an effect on our overall goodness of fit.

Question 1G

To speed this up I made a smaller dataframe based on our previous best model, otherwise the compute time was too long.

```
bestMainDf = data.frame(mpgData$avgMpg, mpgData$model, mpgData$displ, mpgData$year, mpgData$cyl, mpgData$fl)
lModInteractions = lm(formula = mpgData.avgMpg ~ .^2, data = bestMainDf)
```

```
stepModInteractions = stepAIC(lModInteractions, direction="both")
```

```
## Start: AIC=-28.53
```

```

## mpgData.avgMpg ~ (mpgData.model + mpgData.displ + mpgData.year +
##   mpgData.cyl + mpgData.fl)^2
##
##
## Step: AIC=-28.53
## mpgData.avgMpg ~ mpgData.model + mpgData.displ + mpgData.year +
##   mpgData.cyl + mpgData.fl + mpgData.model:mpgData.displ +
##   mpgData.model:mpgData.year + mpgData.model:mpgData.cyl +
##   mpgData.model:mpgData.fl + mpgData.displ:mpgData.year + mpgData.displ:mpgData.cyl +
##   mpgData.displ:mpgData.fl + mpgData.year:mpgData.cyl + mpgData.year:mpgData.fl
##
##
## Step: AIC=-28.53
## mpgData.avgMpg ~ mpgData.model + mpgData.displ + mpgData.year +
##   mpgData.cyl + mpgData.fl + mpgData.model:mpgData.displ +
##   mpgData.model:mpgData.year + mpgData.model:mpgData.cyl +
##   mpgData.model:mpgData.fl + mpgData.displ:mpgData.year + mpgData.displ:mpgData.cyl +
##   mpgData.displ:mpgData.fl + mpgData.year:mpgData.cyl
##
##
## Step: AIC=-28.53
## mpgData.avgMpg ~ mpgData.model + mpgData.displ + mpgData.year +
##   mpgData.cyl + mpgData.fl + mpgData.model:mpgData.displ +
##   mpgData.model:mpgData.year + mpgData.model:mpgData.cyl +
##   mpgData.model:mpgData.fl + mpgData.displ:mpgData.year + mpgData.displ:mpgData.fl +
##   mpgData.year:mpgData.cyl
##
##


|                               | Df | Sum of Sq | RSS    | AIC     |
|-------------------------------|----|-----------|--------|---------|
| - mpgData.model:mpgData.cyl   | 16 | 5.8109    | 63.780 | -38.174 |
| - mpgData.model:mpgData.fl    | 11 | 4.8942    | 62.863 | -31.562 |
| - mpgData.displ:mpgData.fl    | 1  | 0.0240    | 57.993 | -30.431 |
| - mpgData.year:mpgData.cyl    | 2  | 0.8765    | 58.845 | -29.016 |
| <none>                        |    |           | 57.969 | -28.528 |
| - mpgData.displ:mpgData.year  | 1  | 1.1015    | 59.070 | -26.123 |
| - mpgData.model:mpgData.displ | 23 | 14.5069   | 72.476 | -22.265 |
| - mpgData.model:mpgData.year  | 26 | 17.9379   | 75.907 | -17.441 |


##
## Step: AIC=-38.17
## mpgData.avgMpg ~ mpgData.model + mpgData.displ + mpgData.year +
##   mpgData.cyl + mpgData.fl + mpgData.model:mpgData.displ +
##   mpgData.model:mpgData.year + mpgData.model:mpgData.fl + mpgData.displ:mpgData.year +
##   mpgData.displ:mpgData.fl + mpgData.year:mpgData.cyl
##
##


|                              | Df | Sum of Sq | RSS    | AIC     |
|------------------------------|----|-----------|--------|---------|
| - mpgData.model:mpgData.fl   | 11 | 6.1733    | 69.953 | -38.555 |
| - mpgData.displ:mpgData.fl   | 1  | 0.5041    | 64.284 | -38.332 |
| <none>                       |    |           | 63.780 | -38.174 |
| + mpgData.displ:mpgData.cyl  | 2  | 0.8988    | 62.881 | -37.495 |
| + mpgData.year:mpgData.fl    | 1  | 0.1299    | 63.650 | -36.651 |
| + mpgData.cyl:mpgData.fl     | 2  | 0.5566    | 63.223 | -36.225 |
| - mpgData.displ:mpgData.year | 1  | 1.3600    | 65.139 | -35.237 |
| - mpgData.year:mpgData.cyl   | 2  | 2.7693    | 66.549 | -32.228 |
| - mpgData.model:mpgData.year | 28 | 20.1858   | 83.965 | -29.831 |
| + mpgData.model:mpgData.cyl  | 16 | 5.8109    | 57.969 | -28.528 |


```

```
## - mpgData.model:mpgData.displ 29 27.9594 91.739 -11.112
##
## Step: AIC=-38.55
## mpgData.avgMpg ~ mpgData.model + mpgData.displ + mpgData.year +
## mpgData.cyl + mpgData.fl + mpgData.model:mpgData.displ +
## mpgData.model:mpgData.year + mpgData.displ:mpgData.year +
## mpgData.displ:mpgData.fl + mpgData.year:mpgData.cyl
##
##              Df Sum of Sq    RSS    AIC
## <none>                69.953 -38.555
## + mpgData.model:mpgData.fl 11 6.173 63.780 -38.174
## - mpgData.displ:mpgData.year 1 0.866 70.819 -37.674
## + mpgData.displ:mpgData.cyl 2 0.854 69.098 -37.431
## + mpgData.year:mpgData.fl 1 0.063 69.890 -36.764
## - mpgData.year:mpgData.cyl 2 2.426 72.379 -34.578
## + mpgData.cyl:mpgData.fl 3 0.338 69.615 -33.687
## + mpgData.model:mpgData.cyl 16 7.090 62.863 -31.562
## - mpgData.model:mpgData.year 35 71.115 141.068 55.577
## - mpgData.displ:mpgData.fl 3 42.859 112.812 67.274
## - mpgData.model:mpgData.displ 32 80.050 150.003 75.948
```

```
summary(stepModInteractions)
```

```
##
## Call:
## lm(formula = mpgData.avgMpg ~ mpgData.model + mpgData.displ +
## mpgData.year + mpgData.cyl + mpgData.fl + mpgData.model:mpgData.displ +
## mpgData.model:mpgData.year + mpgData.displ:mpgData.year +
## mpgData.displ:mpgData.fl + mpgData.year:mpgData.cyl, data = bestMainDf)
##
## Residuals:
##    Min     1Q   Median     3Q    Max
## -2.25 -0.25  0.00   0.25  2.25
##
## Coefficients: (7 not defined because of singularities)
##              Estimate Std. Error t value
## (Intercept) -1.704e+02  5.307e+02 -0.321
## mpgData.modela4 1.208e+02  3.650e+02  0.331
## mpgData.modela4 quattro 1.606e+02  3.609e+02  0.445
## mpgData.modela6 quattro 4.412e+01  4.506e+02  0.098
## mpgData.modelaltima -1.361e+02  3.835e+02 -0.355
## mpgData.modelc1500 suburban 2wd 8.885e+02  4.331e+02  2.051
## mpgData.modelcamry 6.779e+01  3.517e+02  0.193
## mpgData.modelcamry solara 1.151e+02  3.521e+02  0.327
## mpgData.modelcaravan 2wd 2.523e+02  3.466e+02  0.728
## mpgData.modelcivic -6.029e+02  5.033e+02 -1.198
## mpgData.modelcorolla -1.061e+02  3.967e+02 -0.268
## mpgData.modelcorvette 7.601e+02  4.570e+02  1.663
## mpgData.modeldakota pickup 4wd 2.988e+02  3.584e+02  0.834
## mpgData.modeldurango 4wd 4.781e+02  3.773e+02  1.267
## mpgData.modelexpedition 2wd 7.146e+02  4.375e+02  1.633
## mpgData.modelexplorer 4wd 5.915e+02  3.646e+02  1.622
## mpgData.modelf150 pickup 4wd 5.874e+02  3.833e+02  1.532
## mpgData.modelforester awd 2.207e+02  3.725e+02  0.593
## mpgData.modelgrand cherokee 4wd 7.557e+02  3.681e+02  2.053
```

## mpgData.modelgrand prix	4.285e+02	3.880e+02	1.104
## mpgData.modelgti	-1.949e+02	4.063e+02	-0.480
## mpgData.modelimpreza awd	3.589e+02	3.691e+02	0.972
## mpgData.modeljetta	-1.937e+02	4.063e+02	-0.477
## mpgData.modelk1500 tahoe 4wd	-4.753e+03	8.760e+02	-5.426
## mpgData.modelland cruiser wagon 4wd	-1.148e+00	8.083e+00	-0.142
## mpgData.modelmalibu	7.275e+01	3.649e+02	0.199
## mpgData.modelmaxima	2.359e+00	9.281e+00	0.254
## mpgData.modelmountaineer 4wd	5.113e+02	3.804e+02	1.344
## mpgData.modelmustang	6.994e+02	3.526e+02	1.984
## mpgData.modelnavigator 2wd	8.087e+02	4.344e+02	1.862
## mpgData.modelnew beetle	1.336e+03	1.484e+03	0.900
## mpgData.modelpassat	3.320e+02	3.617e+02	0.918
## mpgData.modelpathfinder 4wd	-2.522e+02	4.431e+02	-0.569
## mpgData.modelram 1500 pickup 4wd	5.451e+02	3.910e+02	1.394
## mpgData.modelrange rover	6.184e+02	4.064e+02	1.522
## mpgData.modelsonata	-1.820e+02	3.626e+02	-0.502
## mpgData.modeltiburon	4.462e+02	3.919e+02	1.139
## mpgData.modeltoyota tacoma 4wd	2.456e+02	3.491e+02	0.703
## mpgData.displ	-1.802e+02	1.512e+02	-1.192
## mpgData.year	9.736e-02	2.660e-01	0.366
## mpgData.cyl5	-7.023e-02	1.147e+00	-0.061
## mpgData.cyl6	2.757e+02	2.080e+02	1.325
## mpgData.cyl8	2.073e+02	3.525e+02	0.588
## mpgData.fld	3.646e+01	3.620e+00	10.072
## mpgData.fle	-1.021e+01	2.880e+00	-3.547
## mpgData.flp	-2.031e+00	1.313e+00	-1.546
## mpgData.flr	2.500e-01	9.679e-01	0.258
## mpgData.modela4:mpgData.displ	-5.381e-01	1.170e+00	-0.460
## mpgData.modela4 quattro:mpgData.displ	4.041e-01	1.154e+00	0.350
## mpgData.modela6 quattro:mpgData.displ	8.398e-01	1.533e+00	0.548
## mpgData.modelaltima:mpgData.displ	-2.202e-01	1.424e+00	-0.155
## mpgData.modelc1500 suburban 2wd:mpgData.displ	-1.937e+00	1.817e+00	-1.066
## mpgData.modelcamry:mpgData.displ	-2.364e-01	1.206e+00	-0.196
## mpgData.modelcamry solara:mpgData.displ	-1.132e+00	1.261e+00	-0.897
## mpgData.modelcaravan 2wd:mpgData.displ	1.804e-01	1.181e+00	0.153
## mpgData.modelcivic:mpgData.displ	-1.516e+01	5.578e+00	-2.717
## mpgData.modelcorolla:mpgData.displ	NA	NA	NA
## mpgData.modelcorvette:mpgData.displ	1.990e-01	1.733e+00	0.115
## mpgData.modeldakota pickup 4wd:mpgData.displ	2.006e+00	1.217e+00	1.649
## mpgData.modeldurango 4wd:mpgData.displ	2.038e+00	1.237e+00	1.648
## mpgData.modelexpedition 2wd:mpgData.displ	2.445e+00	1.835e+00	1.332
## mpgData.modelexplorer 4wd:mpgData.displ	2.665e+00	1.430e+00	1.864
## mpgData.modelf150 pickup 4wd:mpgData.displ	1.390e+00	1.356e+00	1.025
## mpgData.modelforester awd:mpgData.displ	NA	NA	NA
## mpgData.modelgrand cherokee 4wd:mpgData.displ	7.748e-01	1.233e+00	0.628
## mpgData.modelgrand prix:mpgData.displ	1.691e+00	1.329e+00	1.272
## mpgData.modelgti:mpgData.displ	-1.870e+00	1.552e+00	-1.205
## mpgData.modelimpreza awd:mpgData.displ	7.781e-01	2.891e+00	0.269
## mpgData.modeljetta:mpgData.displ	-2.495e+00	1.386e+00	-1.800
## mpgData.modelk1500 tahoe 4wd:mpgData.displ	5.419e+01	7.788e+00	6.957
## mpgData.modelland cruiser wagon 4wd:mpgData.displ	4.443e-01	1.490e+00	0.298
## mpgData.modelmalibu:mpgData.displ	-3.099e-01	1.277e+00	-0.243
## mpgData.modelmaxima:mpgData.displ	7.644e-01	2.994e+00	0.255

## mpgData.modelmountaineer 4wd:mpgData.displ	3.064e+00	1.507e+00	2.033
## mpgData.modelmustang:mpgData.displ	8.943e-02	1.306e+00	0.068
## mpgData.modelnavigator 2wd:mpgData.displ	NA	NA	NA
## mpgData.modelnew beetle:mpgData.displ	1.000e+01	1.288e+01	0.777
## mpgData.modelpassat:mpgData.displ	-2.037e-02	1.113e+00	-0.018
## mpgData.modelpathfinder 4wd:mpgData.displ	7.176e-01	1.343e+00	0.534
## mpgData.modelram 1500 pickup 4wd:mpgData.displ	1.948e+00	1.392e+00	1.399
## mpgData.modelrange rover:mpgData.displ	2.189e+00	2.129e+00	1.028
## mpgData.modelsonata:mpgData.displ	2.553e-01	1.614e+00	0.158
## mpgData.modeltiburon:mpgData.displ	-1.753e+00	1.754e+00	-0.999
## mpgData.modeltoyota tacoma 4wd:mpgData.displ	6.089e-01	1.185e+00	0.514
## mpgData.modela4:mpgData.year	-5.693e-02	1.836e-01	-0.310
## mpgData.modela4 quattro:mpgData.year	-7.895e-02	1.815e-01	-0.435
## mpgData.modela6 quattro:mpgData.year	-2.155e-02	2.269e-01	-0.095
## mpgData.modelaltima:mpgData.year	7.105e-02	1.931e-01	0.368
## mpgData.modelc1500 suburban 2wd:mpgData.year	-4.362e-01	2.166e-01	-2.014
## mpgData.modelcamry:mpgData.year	-3.109e-02	1.770e-01	-0.176
## mpgData.modelcamry solara:mpgData.year	-5.359e-02	1.772e-01	-0.302
## mpgData.modelcaravan 2wd:mpgData.year	-1.252e-01	1.747e-01	-0.717
## mpgData.modelcivic:mpgData.year	3.177e-01	2.553e-01	1.244
## mpgData.modelcorolla:mpgData.year	5.740e-02	1.987e-01	0.289
## mpgData.modelcorvette:mpgData.year	-3.750e-01	2.308e-01	-1.625
## mpgData.modeldakota pickup 4wd:mpgData.year	-1.534e-01	1.804e-01	-0.850
## mpgData.modeldurango 4wd:mpgData.year	-2.432e-01	1.900e-01	-1.280
## mpgData.modelexpedition 2wd:mpgData.year	-3.623e-01	2.210e-01	-1.639
## mpgData.modelexplorer 4wd:mpgData.year	-3.007e-01	1.836e-01	-1.638
## mpgData.modelf150 pickup 4wd:mpgData.year	-2.961e-01	1.933e-01	-1.532
## mpgData.modelforester awd:mpgData.year	-1.090e-01	1.864e-01	-0.585
## mpgData.modelgrand cherokee 4wd:mpgData.year	-3.782e-01	1.854e-01	-2.040
## mpgData.modelgrand prix:mpgData.year	-2.143e-01	1.957e-01	-1.095
## mpgData.modelgti:mpgData.year	1.015e-01	2.038e-01	0.498
## mpgData.modelimpreza awd:mpgData.year	-1.784e-01	1.864e-01	-0.957
## mpgData.modeljetta:mpgData.year	1.015e-01	2.038e-01	0.498
## mpgData.modelk1500 tahoe 4wd:mpgData.year	2.225e+00	4.196e-01	5.303
## mpgData.modelland cruiser wagon 4wd:mpgData.year	NA	NA	NA
## mpgData.modelmalibu:mpgData.year	-3.365e-02	1.837e-01	-0.183
## mpgData.modelmaxima:mpgData.year	NA	NA	NA
## mpgData.modelmountaineer 4wd:mpgData.year	-2.616e-01	1.911e-01	-1.369
## mpgData.modelmustang:mpgData.year	-3.470e-01	1.778e-01	-1.952
## mpgData.modelnavigator 2wd:mpgData.year	-4.026e-01	2.162e-01	-1.862
## mpgData.modelnew beetle:mpgData.year	-6.763e-01	7.548e-01	-0.896
## mpgData.modelpassat:mpgData.year	-1.632e-01	1.820e-01	-0.897
## mpgData.modelpathfinder 4wd:mpgData.year	1.245e-01	2.233e-01	0.558
## mpgData.modelram 1500 pickup 4wd:mpgData.year	-2.766e-01	1.962e-01	-1.410
## mpgData.modelrange rover:mpgData.year	-3.134e-01	2.043e-01	-1.534
## mpgData.modelsonata:mpgData.year	9.249e-02	1.827e-01	0.506
## mpgData.modeltiburon:mpgData.year	-2.197e-01	1.972e-01	-1.114
## mpgData.modeltoyota tacoma 4wd:mpgData.year	-1.238e-01	1.759e-01	-0.704
## mpgData.displ:mpgData.year	8.892e-02	7.550e-02	1.178
## mpgData.displ:mpgData.fld	-1.155e+01	1.448e+00	-7.977
## mpgData.displ:mpgData.fle	1.216e+00	5.793e-01	2.099
## mpgData.displ:mpgData.flp	1.955e-01	2.438e-01	0.802
## mpgData.displ:mpgData.flr	NA	NA	NA
## mpgData.year:mpgData.cyl5	NA	NA	NA

```

## mpgData.year:mpgData.cyl6          -1.378e-01  1.041e-01  -1.324
## mpgData.year:mpgData.cyl8          -1.042e-01  1.761e-01  -0.591
##                                     Pr(>|t|)
## (Intercept)                        0.748786
## mpgData.modela4                    0.741339
## mpgData.modela4 quattro            0.657107
## mpgData.modela6 quattro            0.922171
## mpgData.modelaltima                0.723296
## mpgData.modelc1500 suburban 2wd    0.042567 *
## mpgData.modelcamry                 0.847496
## mpgData.modelcamry solara          0.744402
## mpgData.modelcaravan 2wd           0.468135
## mpgData.modelcivic                 0.233500
## mpgData.modelcorolla               0.789527
## mpgData.modelcorvette              0.099077 .
## mpgData.modeldakota pickup 4wd     0.406165
## mpgData.modeldurango 4wd           0.207744
## mpgData.modelexpedition 2wd        0.105210
## mpgData.modelexplorer 4wd          0.107526
## mpgData.modelf150 pickup 4wd       0.128237
## mpgData.modelforester awd          0.554628
## mpgData.modelgrand cherokee 4wd    0.042395 *
## mpgData.modelgrand prix            0.271785
## mpgData.modelgti                   0.632390
## mpgData.modelimpreza awd           0.333026
## mpgData.modeljetta                 0.634571
## mpgData.modelk1500 tahoe 4wd       3.36e-07 ***
## mpgData.modelland cruiser wagon 4wd 0.887346
## mpgData.modelmalibu                0.842334
## mpgData.modelmaxima                0.799866
## mpgData.modelmountaineer 4wd       0.181575
## mpgData.modelmustang               0.049725 *
## mpgData.modelnavigator 2wd         0.065288 .
## mpgData.modelnew beetle            0.369936
## mpgData.modelpassat                0.360604
## mpgData.modelpathfinder 4wd        0.570373
## mpgData.modelram 1500 pickup 4wd   0.166005
## mpgData.modelrange rover           0.130945
## mpgData.modelsonata                0.616731
## mpgData.modeltiburon               0.257252
## mpgData.modeltoyota tacoma 4wd     0.483246
## mpgData.displ                      0.235747
## mpgData.year                       0.715072
## mpgData.cyl5                       0.951290
## mpgData.cyl6                       0.187707
## mpgData.cyl8                       0.557621
## mpgData.fld                        < 2e-16 ***
## mpgData.fle                        0.000571 ***
## mpgData.flp                        0.124807
## mpgData.flr                        0.796660
## mpgData.modela4:mpgData.displ      0.646503
## mpgData.modela4 quattro:mpgData.displ 0.726893
## mpgData.modela6 quattro:mpgData.displ 0.585029
## mpgData.modelaltima:mpgData.displ  0.877384

```

```

## mpgData.modelc1500 suburban 2wd:mpgData.displ 0.288750
## mpgData.modelcamry:mpgData.displ 0.844979
## mpgData.modelcamry solara:mpgData.displ 0.371382
## mpgData.modelcaravan 2wd:mpgData.displ 0.878845
## mpgData.modelcivic:mpgData.displ 0.007636 **
## mpgData.modelcorolla:mpgData.displ NA
## mpgData.modelcorvette:mpgData.displ 0.908815
## mpgData.modeldakota pickup 4wd:mpgData.displ 0.102029
## mpgData.modeldurango 4wd:mpgData.displ 0.102217
## mpgData.modelexpedition 2wd:mpgData.displ 0.185480
## mpgData.modelexplorer 4wd:mpgData.displ 0.064996 .
## mpgData.modelf150 pickup 4wd:mpgData.displ 0.307521
## mpgData.modelforester awd:mpgData.displ NA
## mpgData.modelgrand cherokee 4wd:mpgData.displ 0.531096
## mpgData.modelgrand prix:mpgData.displ 0.205851
## mpgData.modelgti:mpgData.displ 0.230874
## mpgData.modelimpreza awd:mpgData.displ 0.788289
## mpgData.modeljetta:mpgData.displ 0.074584 .
## mpgData.modelk1500 tahoe 4wd:mpgData.displ 2.47e-10 ***
## mpgData.modelland cruiser wagon 4wd:mpgData.displ 0.766053
## mpgData.modelmalibu:mpgData.displ 0.808742
## mpgData.modelmaxima:mpgData.displ 0.798931
## mpgData.modelmountaineer 4wd:mpgData.displ 0.044433 *
## mpgData.modelmustang:mpgData.displ 0.945545
## mpgData.modelnavigator 2wd:mpgData.displ NA
## mpgData.modelnew beetle:mpgData.displ 0.438895
## mpgData.modelpassat:mpgData.displ 0.985427
## mpgData.modelpathfinder 4wd:mpgData.displ 0.594084
## mpgData.modelram 1500 pickup 4wd:mpgData.displ 0.164558
## mpgData.modelrange rover:mpgData.displ 0.306176
## mpgData.modelsonata:mpgData.displ 0.874624
## mpgData.modeltiburon:mpgData.displ 0.319742
## mpgData.modeltoyota tacoma 4wd:mpgData.displ 0.608200
## mpgData.modela4:mpgData.year 0.757028
## mpgData.modela4 quattro:mpgData.year 0.664491
## mpgData.modela6 quattro:mpgData.year 0.924515
## mpgData.modelaltima:mpgData.year 0.713648
## mpgData.modelc1500 suburban 2wd:mpgData.year 0.046445 *
## mpgData.modelcamry:mpgData.year 0.860904
## mpgData.modelcamry solara:mpgData.year 0.762905
## mpgData.modelcaravan 2wd:mpgData.year 0.475103
## mpgData.modelcivic:mpgData.year 0.215926
## mpgData.modelcorolla:mpgData.year 0.773273
## mpgData.modelcorvette:mpgData.year 0.106931
## mpgData.modeldakota pickup 4wd:mpgData.year 0.397113
## mpgData.modeldurango 4wd:mpgData.year 0.203227
## mpgData.modelexpedition 2wd:mpgData.year 0.104030
## mpgData.modelexplorer 4wd:mpgData.year 0.104301
## mpgData.modelf150 pickup 4wd:mpgData.year 0.128399
## mpgData.modelforester awd:mpgData.year 0.559895
## mpgData.modelgrand cherokee 4wd:mpgData.year 0.043734 *
## mpgData.modelgrand prix:mpgData.year 0.275910
## mpgData.modelgti:mpgData.year 0.619623
## mpgData.modelimpreza awd:mpgData.year 0.340461

```



```
## mpgData.modeljetta:mpgData.year          0.619623
## mpgData.modelk1500 tahoe 4wd:mpgData.year 5.79e-07 ***
## mpgData.modelland cruiser wagon 4wd:mpgData.year      NA
## mpgData.modelmalibu:mpgData.year          0.855009
## mpgData.modelmaxima:mpgData.year          NA
## mpgData.modelmountaineer 4wd:mpgData.year 0.173742
## mpgData.modelmustang:mpgData.year         0.053453 .
## mpgData.modelnavigator 2wd:mpgData.year    0.065295 .
## mpgData.modelnew beetle:mpgData.year      0.372166
## mpgData.modelpassat:mpgData.year          0.371722
## mpgData.modelpathfinder 4wd:mpgData.year  0.578078
## mpgData.modelram 1500 pickup 4wd:mpgData.year 0.161403
## mpgData.modelrange rover:mpgData.year     0.127935
## mpgData.modelsonata:mpgData.year          0.613718
## mpgData.modeltiburon:mpgData.year         0.267656
## mpgData.modeltoyota tacoma 4wd:mpgData.year 0.483084
## mpgData.displ:mpgData.year                0.241366
## mpgData.displ:mpgData.fl                 1.41e-12 ***
## mpgData.displ:mpgData.fl                 0.038089 *
## mpgData.displ:mpgData.fl                 0.424378
## mpgData.displ:mpgData.fl                 NA
## mpgData.year:mpgData.cyl                 NA
## mpgData.year:mpgData.cyl                 0.188112
## mpgData.year:mpgData.cyl                 0.555381
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7903 on 112 degrees of freedom
## Multiple R-squared:  0.9882, Adjusted R-squared:  0.9755
## F-statistic: 77.71 on 121 and 112 DF, p-value: < 2.2e-16
```

Question 1H

```
bestMainInteractionsEffects = lm(formula = mpgData.avgMpg ~ mpgData.model + mpgData.displ + mpgData.year +
  mpgData.cyl + mpgData.fl + mpgData.model:mpgData.displ +
  mpgData.model:mpgData.year + mpgData.displ:mpgData.year +
  mpgData.displ:mpgData.fl + mpgData.year:mpgData.cyl, data = bestMainDf)
summary(bestMainInteractionsEffects)

##
## Call:
## lm(formula = mpgData.avgMpg ~ mpgData.model + mpgData.displ +
##     mpgData.year + mpgData.cyl + mpgData.fl + mpgData.model:mpgData.displ +
##     mpgData.model:mpgData.year + mpgData.displ:mpgData.year +
##     mpgData.displ:mpgData.fl + mpgData.year:mpgData.cyl, data = bestMainDf)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.25  -0.25   0.00   0.25   2.25
##
## Coefficients: (7 not defined because of singularities)
##
##              Estimate Std. Error t value
## (Intercept) -1.704e+02  5.307e+02  -0.321
## mpgData.modela4 1.208e+02  3.650e+02   0.331
```

## mpgData.modela4 quattro	1.606e+02	3.609e+02	0.445
## mpgData.modela6 quattro	4.412e+01	4.506e+02	0.098
## mpgData.modelaltima	-1.361e+02	3.835e+02	-0.355
## mpgData.modelc1500 suburban 2wd	8.885e+02	4.331e+02	2.051
## mpgData.modelcamry	6.779e+01	3.517e+02	0.193
## mpgData.modelcamry solara	1.151e+02	3.521e+02	0.327
## mpgData.modelcaravan 2wd	2.523e+02	3.466e+02	0.728
## mpgData.modelcivic	-6.029e+02	5.033e+02	-1.198
## mpgData.modelcorolla	-1.061e+02	3.967e+02	-0.268
## mpgData.modelcorvette	7.601e+02	4.570e+02	1.663
## mpgData.modeldakota pickup 4wd	2.988e+02	3.584e+02	0.834
## mpgData.modeldurango 4wd	4.781e+02	3.773e+02	1.267
## mpgData.modelexpedition 2wd	7.146e+02	4.375e+02	1.633
## mpgData.modelexplorer 4wd	5.915e+02	3.646e+02	1.622
## mpgData.modelf150 pickup 4wd	5.874e+02	3.833e+02	1.532
## mpgData.modelforester awd	2.207e+02	3.725e+02	0.593
## mpgData.modelgrand cherokee 4wd	7.557e+02	3.681e+02	2.053
## mpgData.modelgrand prix	4.285e+02	3.880e+02	1.104
## mpgData.modelgti	-1.949e+02	4.063e+02	-0.480
## mpgData.modelimpreza awd	3.589e+02	3.691e+02	0.972
## mpgData.modeljetta	-1.937e+02	4.063e+02	-0.477
## mpgData.modelk1500 tahoe 4wd	-4.753e+03	8.760e+02	-5.426
## mpgData.modelland cruiser wagon 4wd	-1.148e+00	8.083e+00	-0.142
## mpgData.modelmalibu	7.275e+01	3.649e+02	0.199
## mpgData.modelmaxima	2.359e+00	9.281e+00	0.254
## mpgData.modelmountaineer 4wd	5.113e+02	3.804e+02	1.344
## mpgData.modelmustang	6.994e+02	3.526e+02	1.984
## mpgData.modelnavigator 2wd	8.087e+02	4.344e+02	1.862
## mpgData.modelnew beetle	1.336e+03	1.484e+03	0.900
## mpgData.modelpassat	3.320e+02	3.617e+02	0.918
## mpgData.modelpathfinder 4wd	-2.522e+02	4.431e+02	-0.569
## mpgData.modelram 1500 pickup 4wd	5.451e+02	3.910e+02	1.394
## mpgData.modelrange rover	6.184e+02	4.064e+02	1.522
## mpgData.modelsonata	-1.820e+02	3.626e+02	-0.502
## mpgData.modeltiburon	4.462e+02	3.919e+02	1.139
## mpgData.modeltoyota tacoma 4wd	2.456e+02	3.491e+02	0.703
## mpgData.displ	-1.802e+02	1.512e+02	-1.192
## mpgData.year	9.736e-02	2.660e-01	0.366
## mpgData.cyl5	-7.023e-02	1.147e+00	-0.061
## mpgData.cyl6	2.757e+02	2.080e+02	1.325
## mpgData.cyl8	2.073e+02	3.525e+02	0.588
## mpgData.fld	3.646e+01	3.620e+00	10.072
## mpgData.fle	-1.021e+01	2.880e+00	-3.547
## mpgData.flp	-2.031e+00	1.313e+00	-1.546
## mpgData.flr	2.500e-01	9.679e-01	0.258
## mpgData.modela4:mpgData.displ	-5.381e-01	1.170e+00	-0.460
## mpgData.modela4 quattro:mpgData.displ	4.041e-01	1.154e+00	0.350
## mpgData.modela6 quattro:mpgData.displ	8.398e-01	1.533e+00	0.548
## mpgData.modelaltima:mpgData.displ	-2.202e-01	1.424e+00	-0.155
## mpgData.modelc1500 suburban 2wd:mpgData.displ	-1.937e+00	1.817e+00	-1.066
## mpgData.modelcamry:mpgData.displ	-2.364e-01	1.206e+00	-0.196
## mpgData.modelcamry solara:mpgData.displ	-1.132e+00	1.261e+00	-0.897
## mpgData.modelcaravan 2wd:mpgData.displ	1.804e-01	1.181e+00	0.153
## mpgData.modelcivic:mpgData.displ	-1.516e+01	5.578e+00	-2.717

## mpgData.modelcorolla:mpgData.displ	NA	NA	NA
## mpgData.modelcorvette:mpgData.displ	1.990e-01	1.733e+00	0.115
## mpgData.modeldakota pickup 4wd:mpgData.displ	2.006e+00	1.217e+00	1.649
## mpgData.modeldurango 4wd:mpgData.displ	2.038e+00	1.237e+00	1.648
## mpgData.modelexpedition 2wd:mpgData.displ	2.445e+00	1.835e+00	1.332
## mpgData.modelexplorer 4wd:mpgData.displ	2.665e+00	1.430e+00	1.864
## mpgData.modelf150 pickup 4wd:mpgData.displ	1.390e+00	1.356e+00	1.025
## mpgData.modelforester awd:mpgData.displ	NA	NA	NA
## mpgData.modelgrand cherokee 4wd:mpgData.displ	7.748e-01	1.233e+00	0.628
## mpgData.modelgrand prix:mpgData.displ	1.691e+00	1.329e+00	1.272
## mpgData.modelgti:mpgData.displ	-1.870e+00	1.552e+00	-1.205
## mpgData.modelimpreza awd:mpgData.displ	7.781e-01	2.891e+00	0.269
## mpgData.modeljetta:mpgData.displ	-2.495e+00	1.386e+00	-1.800
## mpgData.modelk1500 tahoe 4wd:mpgData.displ	5.419e+01	7.788e+00	6.957
## mpgData.modelland cruiser wagon 4wd:mpgData.displ	4.443e-01	1.490e+00	0.298
## mpgData.modelmalibu:mpgData.displ	-3.099e-01	1.277e+00	-0.243
## mpgData.modelmaxima:mpgData.displ	7.644e-01	2.994e+00	0.255
## mpgData.modelmountaineer 4wd:mpgData.displ	3.064e+00	1.507e+00	2.033
## mpgData.modelmustang:mpgData.displ	8.943e-02	1.306e+00	0.068
## mpgData.modelnavigator 2wd:mpgData.displ	NA	NA	NA
## mpgData.modelnew beetle:mpgData.displ	1.000e+01	1.288e+01	0.777
## mpgData.modelpassat:mpgData.displ	-2.037e-02	1.113e+00	-0.018
## mpgData.modelpathfinder 4wd:mpgData.displ	7.176e-01	1.343e+00	0.534
## mpgData.modelram 1500 pickup 4wd:mpgData.displ	1.948e+00	1.392e+00	1.399
## mpgData.modelrange rover:mpgData.displ	2.189e+00	2.129e+00	1.028
## mpgData.modelsonata:mpgData.displ	2.553e-01	1.614e+00	0.158
## mpgData.modeltiburon:mpgData.displ	-1.753e+00	1.754e+00	-0.999
## mpgData.modeltoyota tacoma 4wd:mpgData.displ	6.089e-01	1.185e+00	0.514
## mpgData.modela4:mpgData.year	-5.693e-02	1.836e-01	-0.310
## mpgData.modela4 quattro:mpgData.year	-7.895e-02	1.815e-01	-0.435
## mpgData.modela6 quattro:mpgData.year	-2.155e-02	2.269e-01	-0.095
## mpgData.modelaltima:mpgData.year	7.105e-02	1.931e-01	0.368
## mpgData.modelc1500 suburban 2wd:mpgData.year	-4.362e-01	2.166e-01	-2.014
## mpgData.modelcamry:mpgData.year	-3.109e-02	1.770e-01	-0.176
## mpgData.modelcamry solara:mpgData.year	-5.359e-02	1.772e-01	-0.302
## mpgData.modelcaravan 2wd:mpgData.year	-1.252e-01	1.747e-01	-0.717
## mpgData.modelcivic:mpgData.year	3.177e-01	2.553e-01	1.244
## mpgData.modelcorolla:mpgData.year	5.740e-02	1.987e-01	0.289
## mpgData.modelcorvette:mpgData.year	-3.750e-01	2.308e-01	-1.625
## mpgData.modeldakota pickup 4wd:mpgData.year	-1.534e-01	1.804e-01	-0.850
## mpgData.modeldurango 4wd:mpgData.year	-2.432e-01	1.900e-01	-1.280
## mpgData.modelexpedition 2wd:mpgData.year	-3.623e-01	2.210e-01	-1.639
## mpgData.modelexplorer 4wd:mpgData.year	-3.007e-01	1.836e-01	-1.638
## mpgData.modelf150 pickup 4wd:mpgData.year	-2.961e-01	1.933e-01	-1.532
## mpgData.modelforester awd:mpgData.year	-1.090e-01	1.864e-01	-0.585
## mpgData.modelgrand cherokee 4wd:mpgData.year	-3.782e-01	1.854e-01	-2.040
## mpgData.modelgrand prix:mpgData.year	-2.143e-01	1.957e-01	-1.095
## mpgData.modelgti:mpgData.year	1.015e-01	2.038e-01	0.498
## mpgData.modelimpreza awd:mpgData.year	-1.784e-01	1.864e-01	-0.957
## mpgData.modeljetta:mpgData.year	1.015e-01	2.038e-01	0.498
## mpgData.modelk1500 tahoe 4wd:mpgData.year	2.225e+00	4.196e-01	5.303
## mpgData.modelland cruiser wagon 4wd:mpgData.year	NA	NA	NA
## mpgData.modelmalibu:mpgData.year	-3.365e-02	1.837e-01	-0.183
## mpgData.modelmaxima:mpgData.year	NA	NA	NA

## mpgData.modelmountaineer 4wd:mpgData.year	-2.616e-01	1.911e-01	-1.369
## mpgData.modelmustang:mpgData.year	-3.470e-01	1.778e-01	-1.952
## mpgData.modelnavigator 2wd:mpgData.year	-4.026e-01	2.162e-01	-1.862
## mpgData.modelnew beetle:mpgData.year	-6.763e-01	7.548e-01	-0.896
## mpgData.modelpassat:mpgData.year	-1.632e-01	1.820e-01	-0.897
## mpgData.modelpathfinder 4wd:mpgData.year	1.245e-01	2.233e-01	0.558
## mpgData.modelram 1500 pickup 4wd:mpgData.year	-2.766e-01	1.962e-01	-1.410
## mpgData.modelrange rover:mpgData.year	-3.134e-01	2.043e-01	-1.534
## mpgData.modelsonata:mpgData.year	9.249e-02	1.827e-01	0.506
## mpgData.modeltiburon:mpgData.year	-2.197e-01	1.972e-01	-1.114
## mpgData.modeltoyota tacoma 4wd:mpgData.year	-1.238e-01	1.759e-01	-0.704
## mpgData.displ:mpgData.year	8.892e-02	7.550e-02	1.178
## mpgData.displ:mpgData.fld	-1.155e+01	1.448e+00	-7.977
## mpgData.displ:mpgData.fle	1.216e+00	5.793e-01	2.099
## mpgData.displ:mpgData.flp	1.955e-01	2.438e-01	0.802
## mpgData.displ:mpgData.flr	NA	NA	NA
## mpgData.year:mpgData.cyl5	NA	NA	NA
## mpgData.year:mpgData.cyl6	-1.378e-01	1.041e-01	-1.324
## mpgData.year:mpgData.cyl8	-1.042e-01	1.761e-01	-0.591
##	Pr(> t)		
## (Intercept)	0.748786		
## mpgData.modela4	0.741339		
## mpgData.modela4 quattro	0.657107		
## mpgData.modela6 quattro	0.922171		
## mpgData.modelaltima	0.723296		
## mpgData.modelc1500 suburban 2wd	0.042567 *		
## mpgData.modelcamry	0.847496		
## mpgData.modelcamry solara	0.744402		
## mpgData.modelcaravan 2wd	0.468135		
## mpgData.modelcivic	0.233500		
## mpgData.modelcorolla	0.789527		
## mpgData.modelcorvette	0.099077 .		
## mpgData.modeldakota pickup 4wd	0.406165		
## mpgData.modeldurango 4wd	0.207744		
## mpgData.modelexpedition 2wd	0.105210		
## mpgData.modelexplorer 4wd	0.107526		
## mpgData.modelf150 pickup 4wd	0.128237		
## mpgData.modelforester awd	0.554628		
## mpgData.modelgrand cherokee 4wd	0.042395 *		
## mpgData.modelgrand prix	0.271785		
## mpgData.modelgti	0.632390		
## mpgData.modelimpreza awd	0.333026		
## mpgData.modeljetta	0.634571		
## mpgData.modelk1500 tahoe 4wd	3.36e-07 ***		
## mpgData.modelland cruiser wagon 4wd	0.887346		
## mpgData.modelmalibu	0.842334		
## mpgData.modelmaxima	0.799866		
## mpgData.modelmountaineer 4wd	0.181575		
## mpgData.modelmustang	0.049725 *		
## mpgData.modelnavigator 2wd	0.065288 .		
## mpgData.modelnew beetle	0.369936		
## mpgData.modelpassat	0.360604		
## mpgData.modelpathfinder 4wd	0.570373		
## mpgData.modelram 1500 pickup 4wd	0.166005		

```

## mpgData.modelrange rover 0.130945
## mpgData.modelsonata 0.616731
## mpgData.modeltiburon 0.257252
## mpgData.modeltoyota tacoma 4wd 0.483246
## mpgData.displ 0.235747
## mpgData.year 0.715072
## mpgData.cyl5 0.951290
## mpgData.cyl6 0.187707
## mpgData.cyl8 0.557621
## mpgData.fld < 2e-16 ***
## mpgData.fle 0.000571 ***
## mpgData.flp 0.124807
## mpgData.flr 0.796660
## mpgData.modela4:mpgData.displ 0.646503
## mpgData.modela4 quattro:mpgData.displ 0.726893
## mpgData.modela6 quattro:mpgData.displ 0.585029
## mpgData.modelaltima:mpgData.displ 0.877384
## mpgData.modelc1500 suburban 2wd:mpgData.displ 0.288750
## mpgData.modelcamry:mpgData.displ 0.844979
## mpgData.modelcamry solara:mpgData.displ 0.371382
## mpgData.modelcaravan 2wd:mpgData.displ 0.878845
## mpgData.modelcivic:mpgData.displ 0.007636 **
## mpgData.modelcorolla:mpgData.displ NA
## mpgData.modelcorvette:mpgData.displ 0.908815
## mpgData.modeldakota pickup 4wd:mpgData.displ 0.102029
## mpgData.modeldurango 4wd:mpgData.displ 0.102217
## mpgData.modelexpedition 2wd:mpgData.displ 0.185480
## mpgData.modelexplorer 4wd:mpgData.displ 0.064996 .
## mpgData.modelf150 pickup 4wd:mpgData.displ 0.307521
## mpgData.modelforester awd:mpgData.displ NA
## mpgData.modelgrand cherokee 4wd:mpgData.displ 0.531096
## mpgData.modelgrand prix:mpgData.displ 0.205851
## mpgData.modelgti:mpgData.displ 0.230874
## mpgData.modelimpreza awd:mpgData.displ 0.788289
## mpgData.modeljetta:mpgData.displ 0.074584 .
## mpgData.modelk1500 tahoe 4wd:mpgData.displ 2.47e-10 ***
## mpgData.modelland cruiser wagon 4wd:mpgData.displ 0.766053
## mpgData.modelmalibu:mpgData.displ 0.808742
## mpgData.modelmaxima:mpgData.displ 0.798931
## mpgData.modelmountaineer 4wd:mpgData.displ 0.044433 *
## mpgData.modelmustang:mpgData.displ 0.945545
## mpgData.modelnavigator 2wd:mpgData.displ NA
## mpgData.modelnew beetle:mpgData.displ 0.438895
## mpgData.modelpassat:mpgData.displ 0.985427
## mpgData.modelpathfinder 4wd:mpgData.displ 0.594084
## mpgData.modelram 1500 pickup 4wd:mpgData.displ 0.164558
## mpgData.modelrange rover:mpgData.displ 0.306176
## mpgData.modelsonata:mpgData.displ 0.874624
## mpgData.modeltiburon:mpgData.displ 0.319742
## mpgData.modeltoyota tacoma 4wd:mpgData.displ 0.608200
## mpgData.modela4:mpgData.year 0.757028
## mpgData.modela4 quattro:mpgData.year 0.664491
## mpgData.modela6 quattro:mpgData.year 0.924515
## mpgData.modelaltima:mpgData.year 0.713648

```

```
## mpgData.modelc1500 suburban 2wd:mpgData.year      0.046445 *
## mpgData.modelcamry:mpgData.year                  0.860904
## mpgData.modelcamry solara:mpgData.year            0.762905
## mpgData.modelcaravan 2wd:mpgData.year            0.475103
## mpgData.modelcivic:mpgData.year                  0.215926
## mpgData.modelcorolla:mpgData.year                0.773273
## mpgData.modelcorvette:mpgData.year               0.106931
## mpgData.modeldakota pickup 4wd:mpgData.year       0.397113
## mpgData.modeldurango 4wd:mpgData.year            0.203227
## mpgData.modelexpedition 2wd:mpgData.year         0.104030
## mpgData.modelexplorer 4wd:mpgData.year           0.104301
## mpgData.modelf150 pickup 4wd:mpgData.year        0.128399
## mpgData.modelforester awd:mpgData.year           0.559895
## mpgData.modelgrand cherokee 4wd:mpgData.year     0.043734 *
## mpgData.modelgrand prix:mpgData.year            0.275910
## mpgData.modelgti:mpgData.year                   0.619623
## mpgData.modelimpreza awd:mpgData.year            0.340461
## mpgData.modeljetta:mpgData.year                  0.619623
## mpgData.modelk1500 tahoe 4wd:mpgData.year        5.79e-07 ***
## mpgData.modellland cruiser wagon 4wd:mpgData.year NA
## mpgData.modelmalibu:mpgData.year                 0.855009
## mpgData.modelmaxima:mpgData.year                 NA
## mpgData.modelmountaineer 4wd:mpgData.year        0.173742
## mpgData.modelmustang:mpgData.year               0.053453 .
## mpgData.modelnavigator 2wd:mpgData.year          0.065295 .
## mpgData.modelnew beetle:mpgData.year            0.372166
## mpgData.modelpassat:mpgData.year                0.371722
## mpgData.modelpathfinder 4wd:mpgData.year        0.578078
## mpgData.modelram 1500 pickup 4wd:mpgData.year    0.161403
## mpgData.modelrange rover:mpgData.year           0.127935
## mpgData.modelsonata:mpgData.year                 0.613718
## mpgData.modeltiburon:mpgData.year               0.267656
## mpgData.modeltoyota tacoma 4wd:mpgData.year      0.483084
## mpgData.displ:mpgData.year                       0.241366
## mpgData.displ:mpgData.fld                        1.41e-12 ***
## mpgData.displ:mpgData.fle                        0.038089 *
## mpgData.displ:mpgData.flp                        0.424378
## mpgData.displ:mpgData.flr                        NA
## mpgData.year:mpgData.cyl5                        NA
## mpgData.year:mpgData.cyl6                        0.188112
## mpgData.year:mpgData.cyl8                        0.555381
```

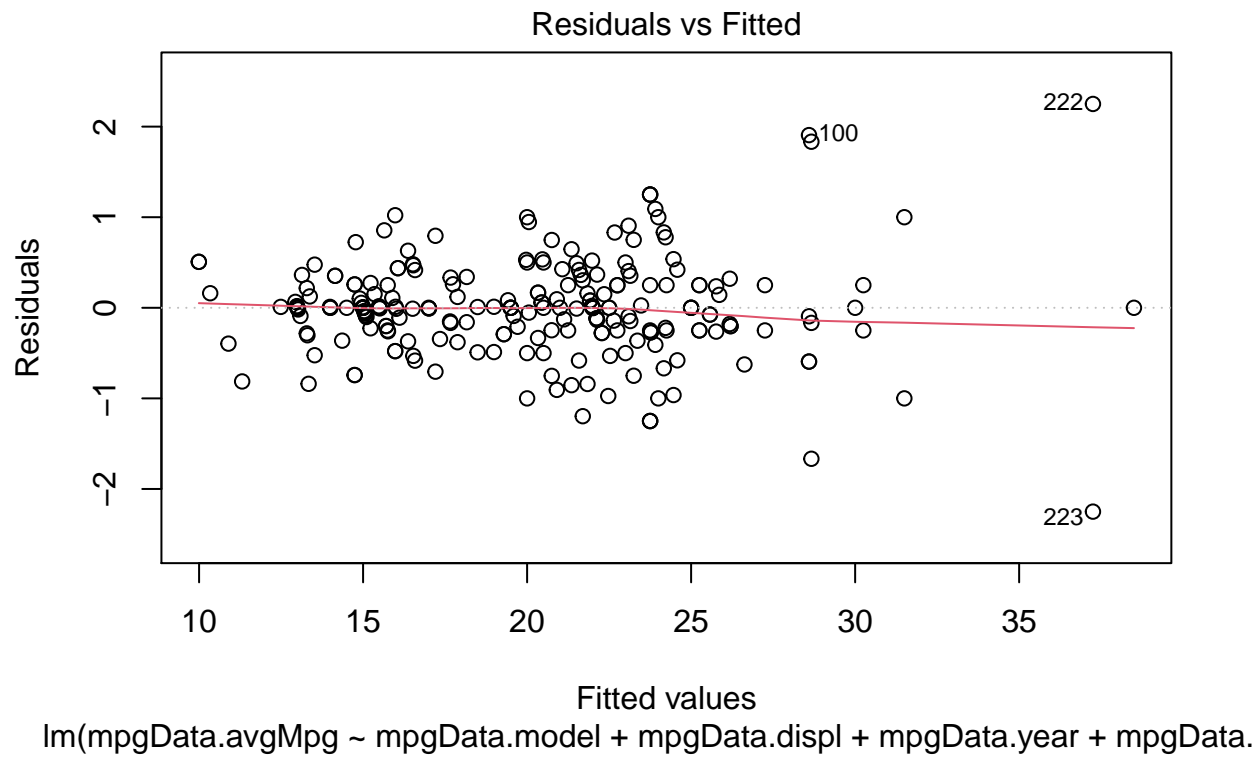
```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

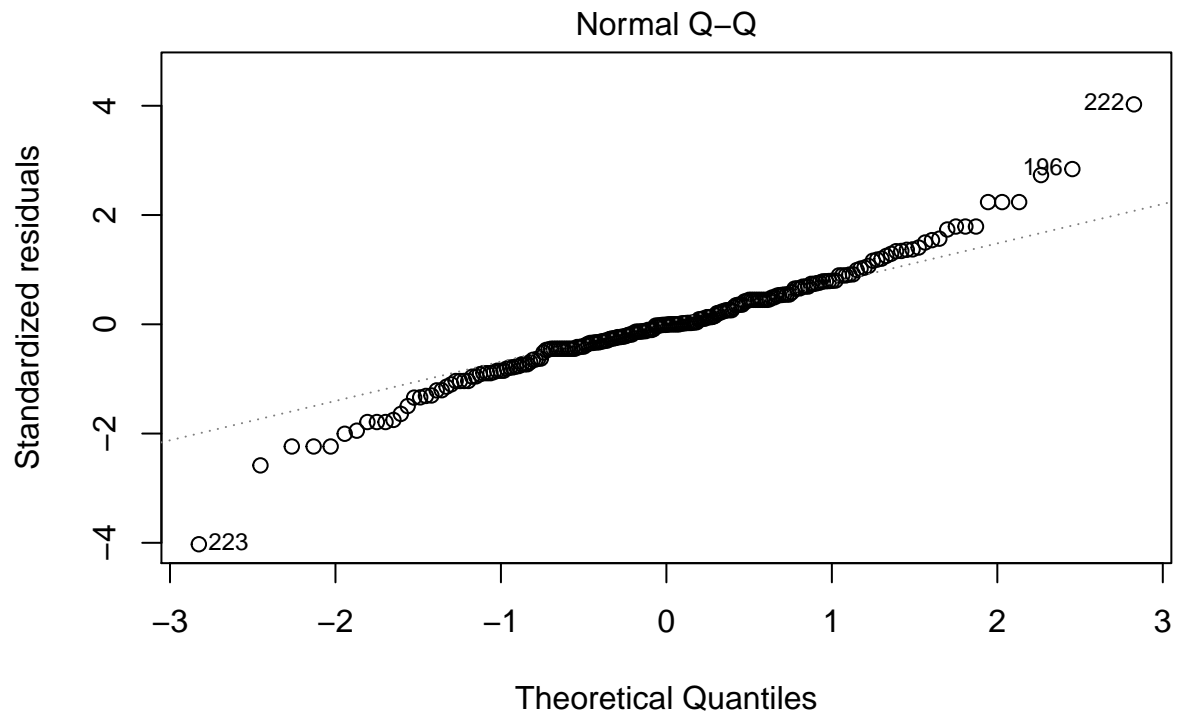
```
## Residual standard error: 0.7903 on 112 degrees of freedom
## Multiple R-squared:  0.9882, Adjusted R-squared:  0.9755
## F-statistic: 77.71 on 121 and 112 DF, p-value: < 2.2e-16
```

```
plot(bestMainInteractionsEffects)
```

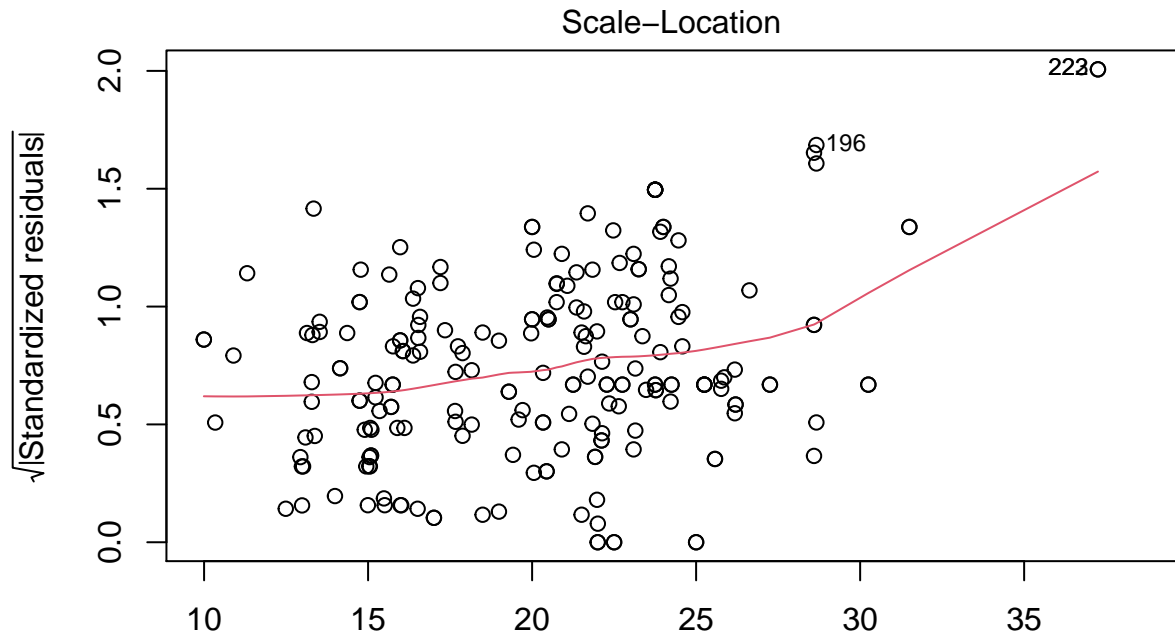
```
## Warning: not plotting observations with leverage one:
```

```
## 16, 17, 18, 22, 23, 28, 31, 32, 75, 76, 77, 107, 108, 123, 137, 150, 153, 154, 199, 200, 212, 213
```





$\text{lm}(\text{mpgData.avgMpg} \sim \text{mpgData.model} + \text{mpgData.displ} + \text{mpgData.year} + \text{mpgData.}$

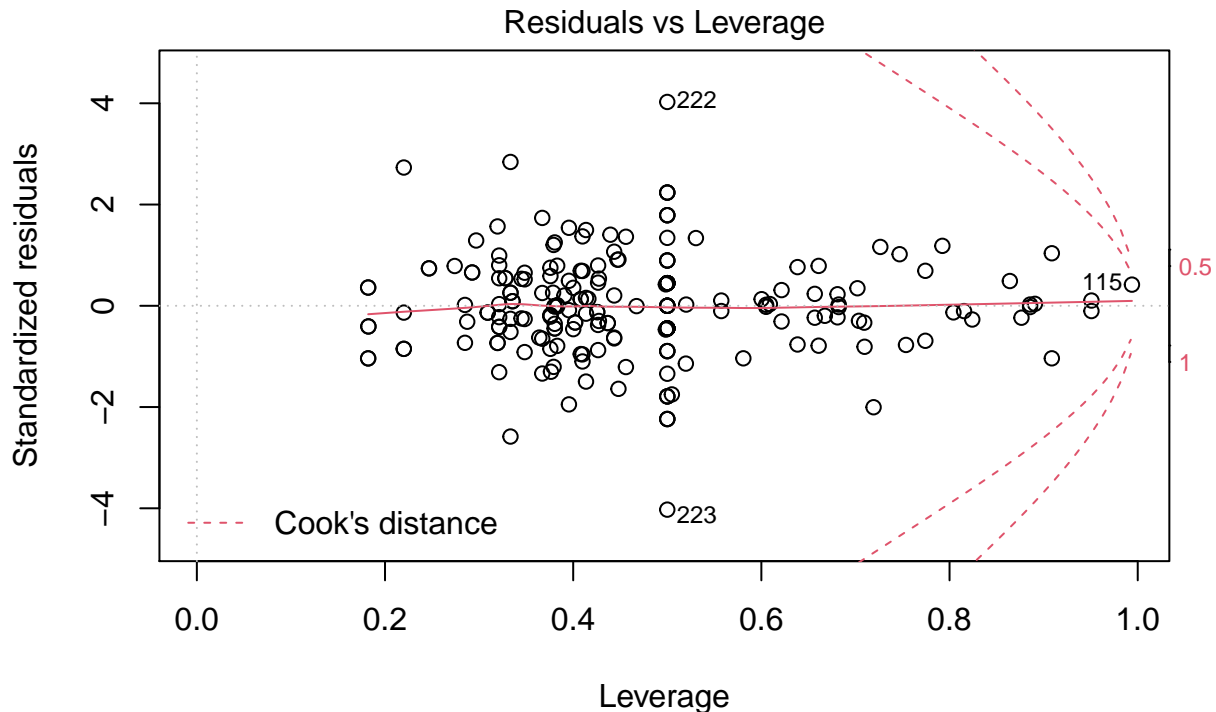


Fitted values

$\text{lm}(\text{mpgData.avgMpg} \sim \text{mpgData.model} + \text{mpgData.displ} + \text{mpgData.year} + \text{mpgData.}$

```
## Warning in sqrt(crit * p * (1 - hh)/hh): NaNs produced
```

```
## Warning in sqrt(crit * p * (1 - hh)/hh): NaNs produced
```



$\text{lm}(\text{mpgData.avgMpg} \sim \text{mpgData.model} + \text{mpgData.displ} + \text{mpgData.year} + \text{mpgData.}$

The model with interactions shares most of the same qualities as the initial model. R-squared and Adj-Rsquared are both higher, suggesting we explain more variance in the data which makes sense as our model is including the interaction effects of most of the categorical variables in our main model.

The first residuals graph is even more linear with less clustering, and appears to have fewer outliers still making linear regression a good choice.

The QQ plot tails are less skewed and closer to our main line which suggests we've compensated for some of the skewed, non-linear effects we were seeing when we did not include the interactions.

The Scale-Location graph has skewed even more, however. Suggesting greater heteroskedasticity than we saw in our initial model. Due to the size difference, we may have some underlying issues in our data and model selection that need to be addressed to make our predictions more precise.

Lastly, the residuals vs leverage plot looks much better with all of the extreme values being pulled closer together with a shorter Cook's distance and having a less extreme effect on our model overall.

Question 1I

Most of our predictors have pretty small effects that when combined add up to a decent avgMPG. This is likely due to the relatively large number of factors in the categorical variables, each having a small effect that adds up once combined with the other factors. The intercept suggests an avgMPG of less than 0, which is impossible, but once combined with the model, model interactions, displacement, year, fuel type, etc. we get a main effect. It looks like the base case is a 4 cylinder, using 'c' fuel, 4runner.

Question 1J

Based on the accuracy of the models, I would have chosen the one with the interaction variables. It's very similar to the model without the interactions but the graphs show a much cleaner, more linear picture

that is closer to normality. This combined with the adjusted r-squared increase of almost 2.5% makes me want to use the model with interactions over the other.