

Case Study 3 – Regression Diagnostics

```
library(tidyverse)
```

```
-- Attaching core tidyverse packages ----- tidyverse 2.0.0 --
v dplyr      1.1.2      v readr      2.1.4
v forcats    1.0.0      v stringr    1.5.0
v ggplot2    3.4.3      v tibble     3.2.1
v lubridate  1.9.2      v tidyr      1.3.0
v purrr      1.0.2
-- Conflicts ----- tidyverse_conflicts() --
x dplyr::filter() masks stats::filter()
x dplyr::lag()     masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become
```

```
library(DescTools)
library(plotly)
```

Attaching package: 'plotly'

The following object is masked from 'package:ggplot2':

last_plot

The following object is masked from 'package:stats':

filter

The following object is masked from 'package:graphics':

layout

Prediction Error

$$s_{\hat{y}_p} = \sqrt{s^2 \left[\frac{1}{n} + \frac{(x_p - \bar{X})^2}{SS_X} \right]}$$

Car stopping distance

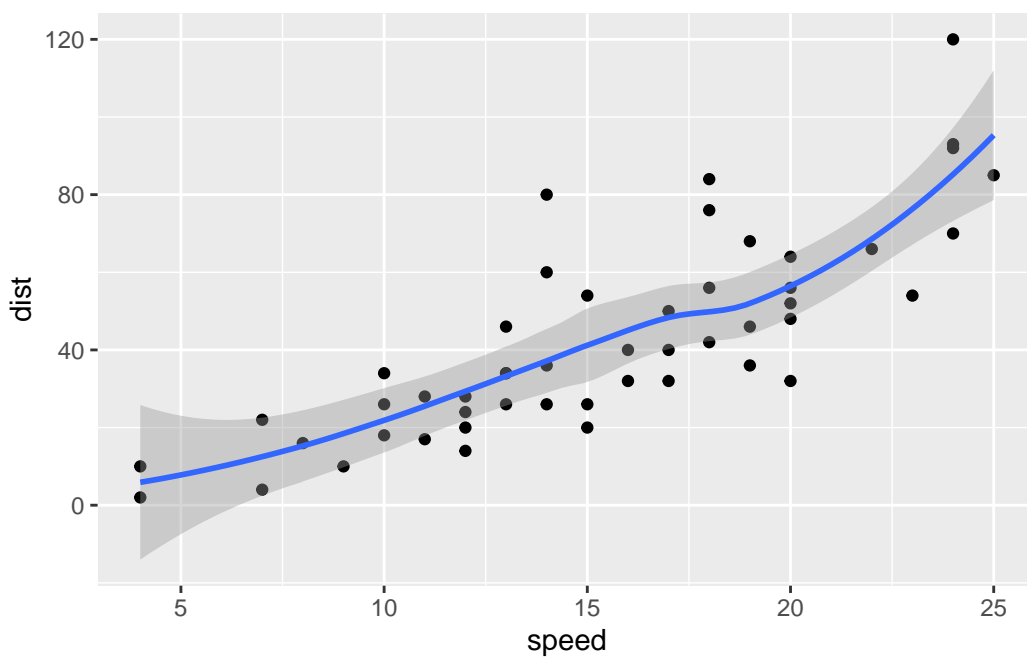
Three models

```
cars.lm <- lm(dist~speed,data=cars)
cars.sqm <- lm(sqrt(dist)~speed,data=cars)
cars.llm <- lm(log(dist)~speed,data=cars)
```

Linear

```
ggplot(cars,aes(x=speed,y=dist)) + geom_point() + geom_smooth()
```

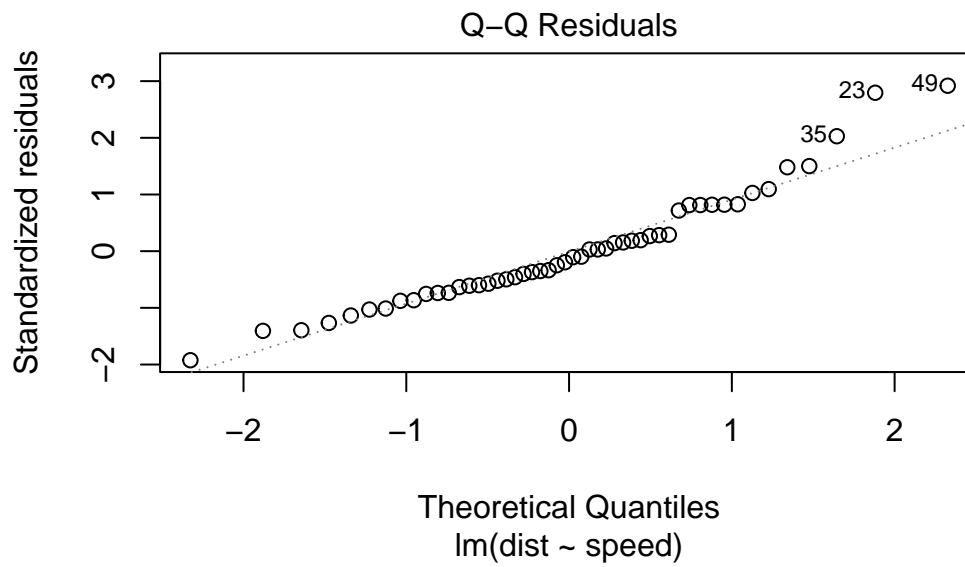
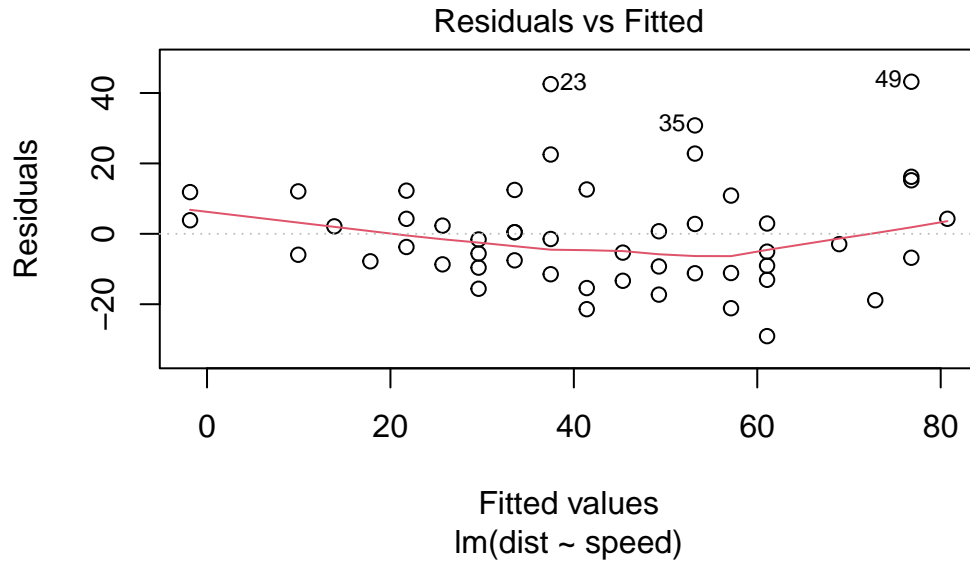
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'

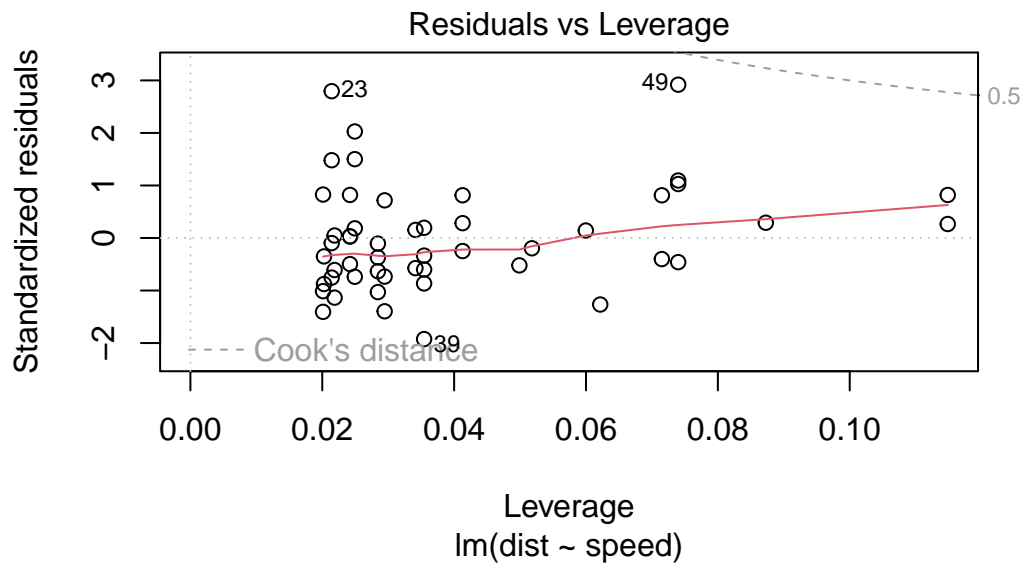
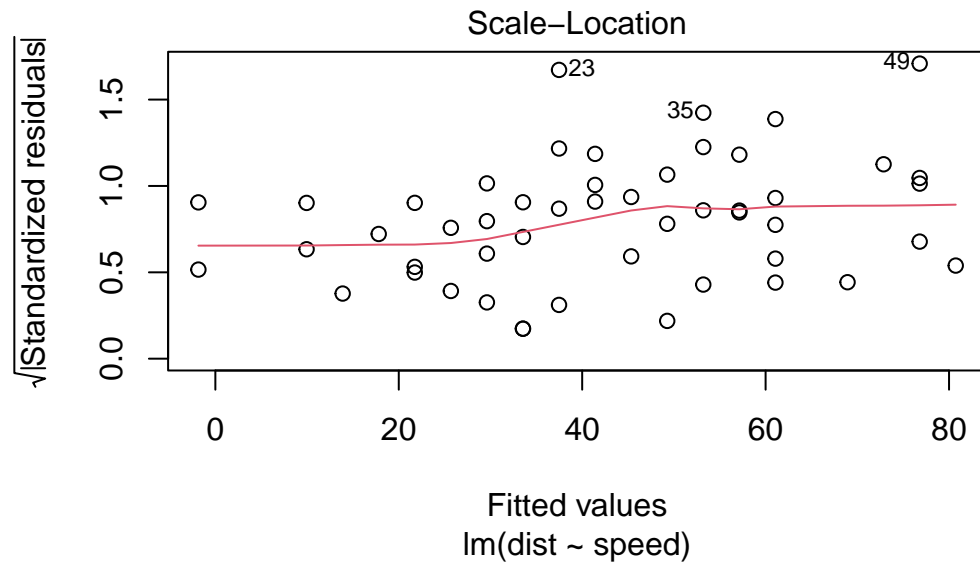


If you have loaded the plotly package, you can get an interactive version of the last scatterplot with `ggplotly()` [I've turned it off here to generate pdf output, only works for html output.]

```
ggplotly()
```

```
plot(cars.lm)
```

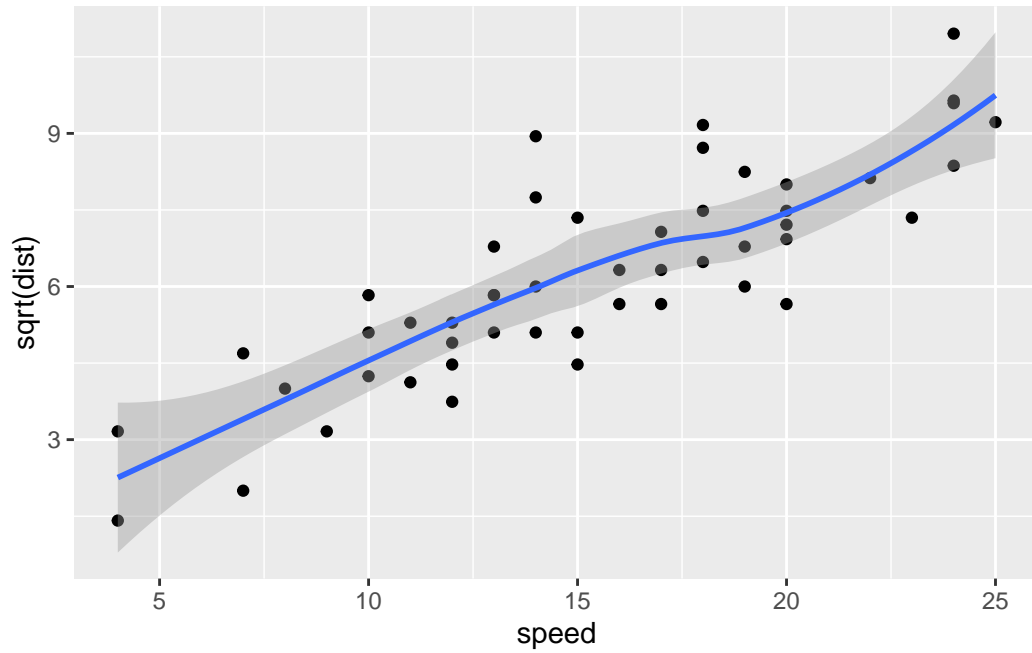




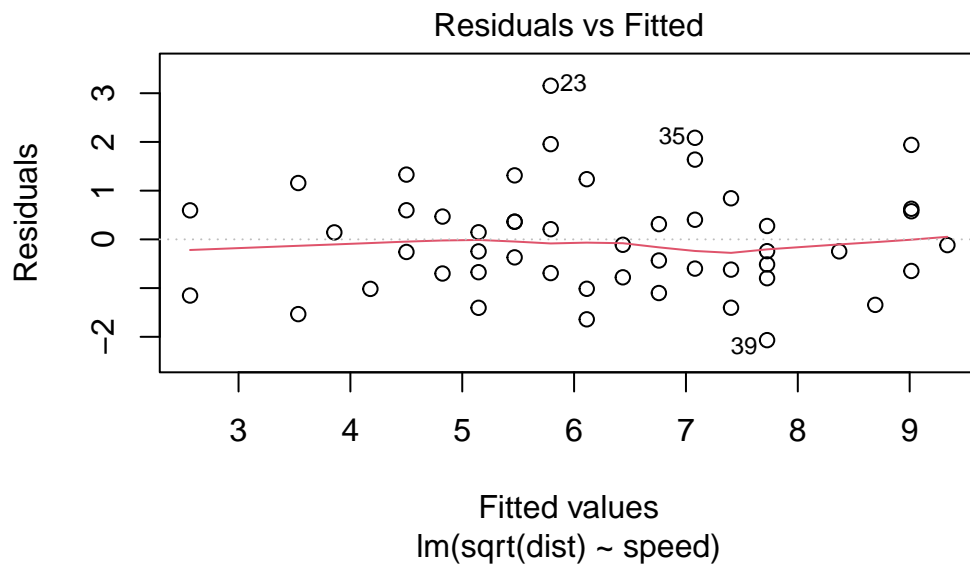
Square Root

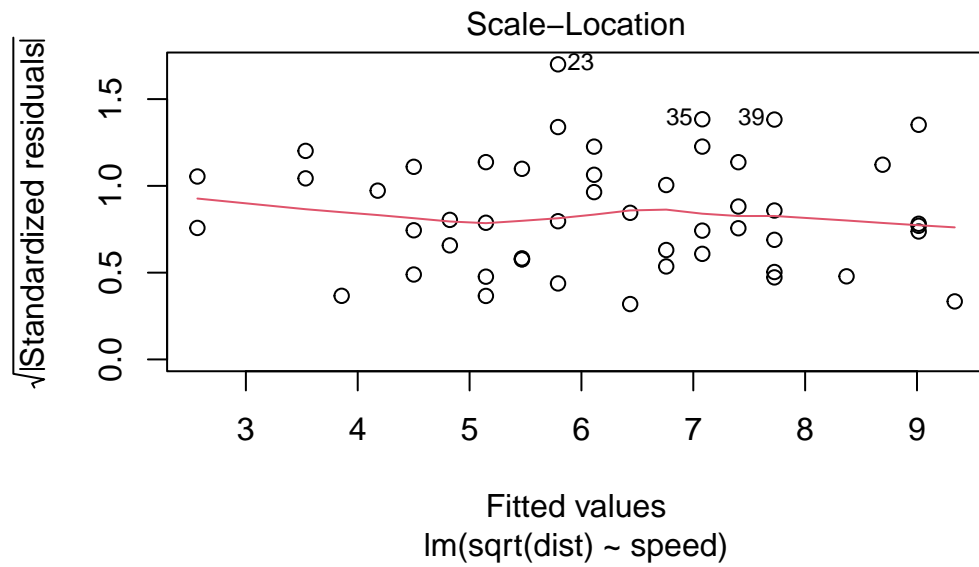
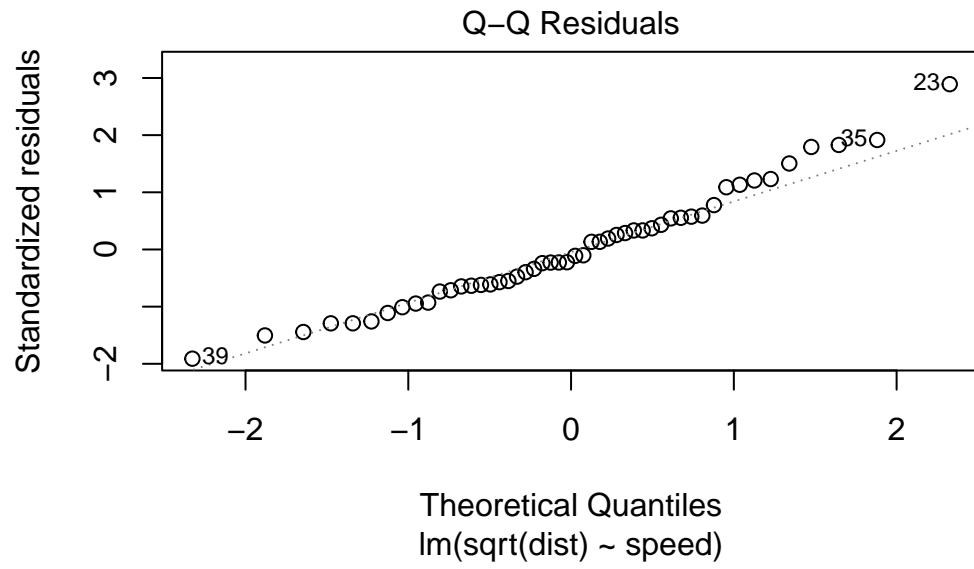
```
ggplot(cars, aes(x=speed, y=sqrt(dist))) + geom_point() + geom_smooth()
```

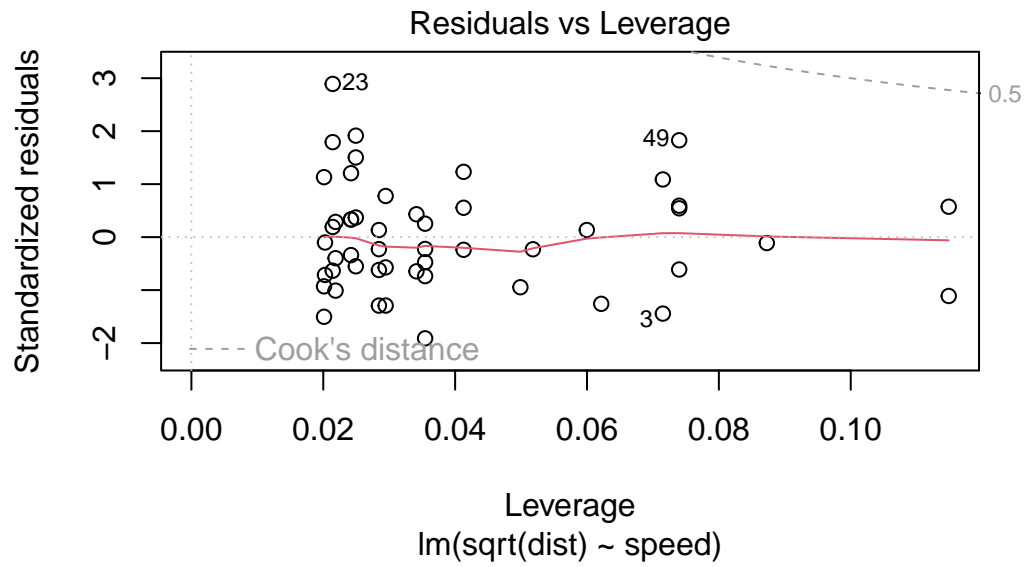
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'



```
plot(cars.sqm)
```



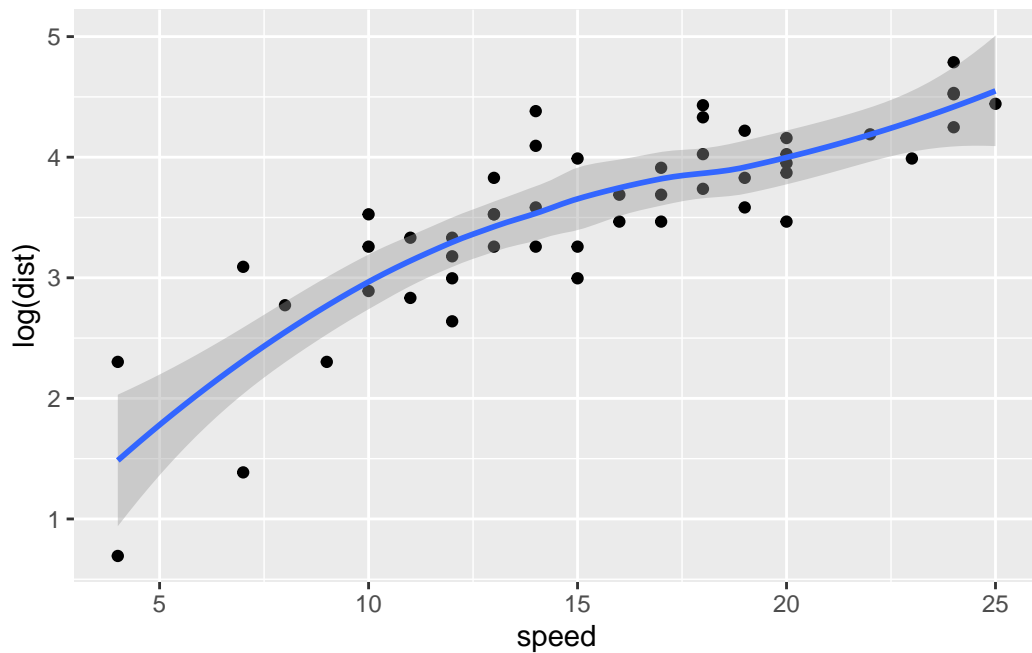




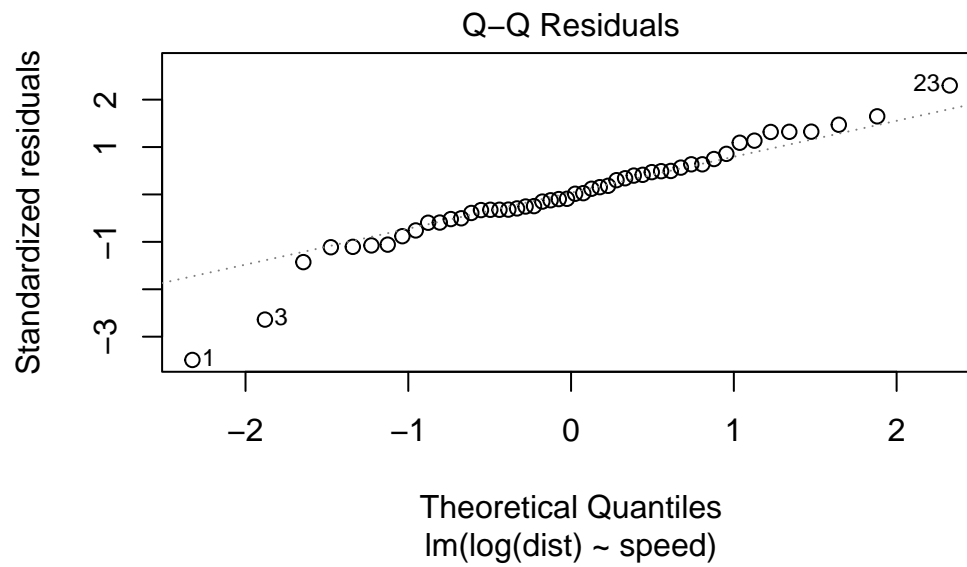
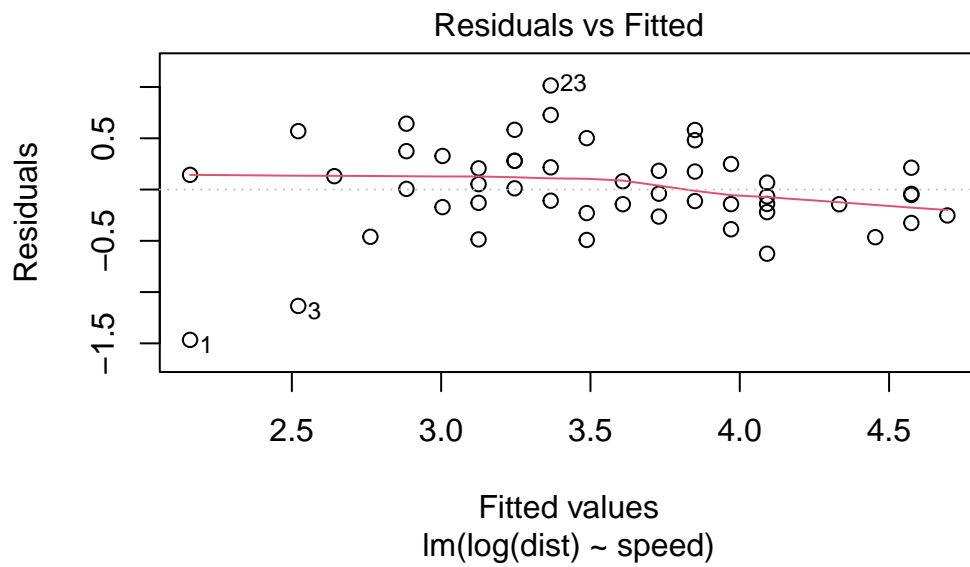
Log

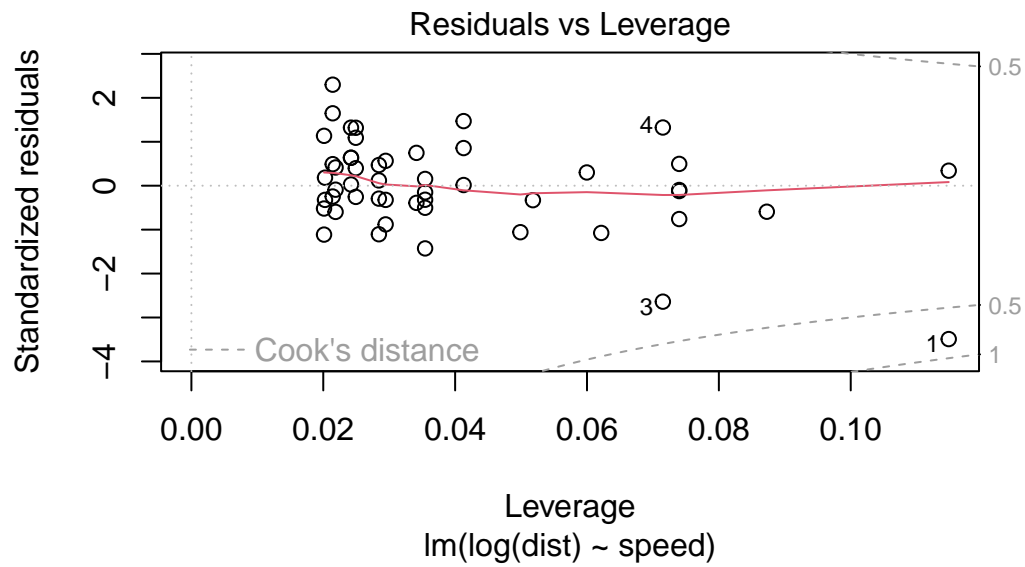
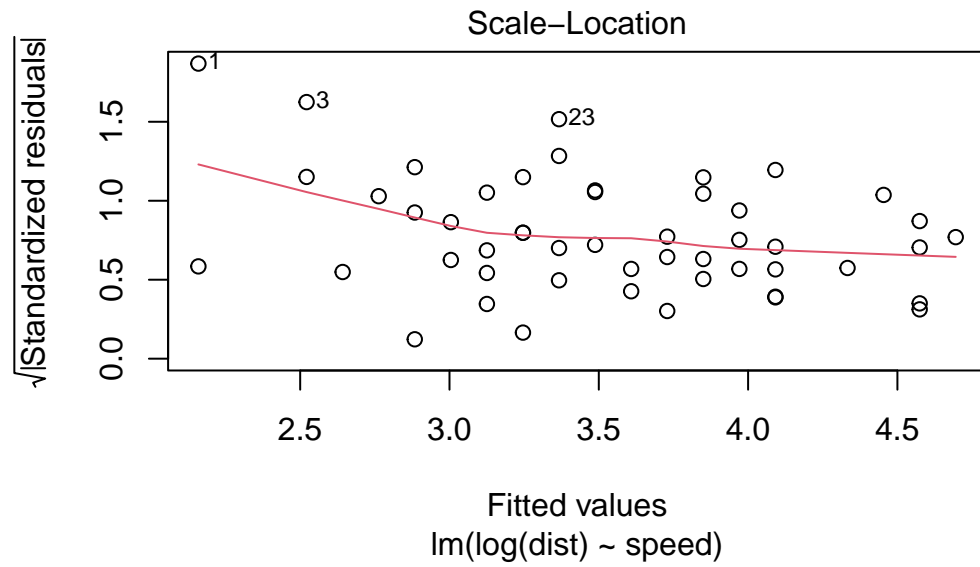
```
ggplot(cars, aes(x=speed, y=log(dist))) + geom_point() + geom_smooth()
```

`geom_smooth()` using method = 'loess' and formula = 'y ~ x'



```
plot(cars.llm)
```





ACED Data

```
ACEDextract <- read_csv("ACED_extract1.csv", na = "-999")
```

Rows: 290 Columns: 29

-- Column specification -----

Delimiter: ","

chr (7): SubjID, Session, Cond_code, Sequencing, Feedback, Gender, Level_Code
dbl (22): Correct, Incorrect, Reamaining, ElapsedTime, Race, pre_scaled, pos...

i Use `spec()` to retrieve the full column specification for this data.

i Specify the column types or set `show_col_types = FALSE` to quiet this message.

```
ACEDextract$Session <- factor(ACEDextract$Session)
ACEDextract$Cond_code <- factor(ACEDextract$Cond_code)
ACEDextract$Sequencing <- factor(ACEDextract$Sequencing)
ACEDextract$Feedback <- factor(ACEDextract$Feedback)
ACEDextract$Gender <- factor(ACEDextract$Gender)
ACEDextract$Race <- factor(ACEDextract$Race,1:8)
ACEDextract$Level_Code <- factor(ACEDextract$Level_Code)
```

```
ACEDextract %>%
  mutate(gain=post_scaled-pre_scaled) ->
  ACEDextract
```

dfbetas

```
lm_PostxEAP <- lm(EAP.sgp~post_scaled,data=ACEDextract,na.action=na.exclude)
dfb <- dfbeta(lm_PostxEAP)
dfbs <- dfbetas(lm_PostxEAP)
data.frame(dfbeta=dfb,dfbeta_scaled=dfbs) ->dfbb
summary(dfbb)
```

dfbeta..Intercept.	dfbeta.post_scaled	dfbeta_scaled..Intercept.
Min. : -2.202e-02	Min. : -6.715e-04	Min. : -1.263e-01
1st Qu.: -3.563e-03	1st Qu.: -5.982e-05	1st Qu.: -2.039e-02
Median : 0.000e+00	Median : 0.000e+00	Median : 0.000e+00
Mean : 3.980e-06	Mean : -2.790e-08	Mean : 3.613e-05
3rd Qu.: 2.987e-03	3rd Qu.: 4.484e-05	3rd Qu.: 1.707e-02
Max. : 3.594e-02	Max. : 4.571e-04	Max. : 2.088e-01

dfbeta_scaled.post_scaled
Min. : -0.2183489
1st Qu.: -0.0193745
Median : 0.0000000
Mean : -0.0000108

3rd Qu.: 0.0144733
 Max. : 0.1482344

dfbb

	dfbeta..Intercept.	dfbeta.post_scaled	dfbeta_scaled..Intercept.
1	-0.0107997611	2.158032e-04	-0.0617189357
2	0.0049771633	-7.922792e-05	0.0284315957
3	-0.0131832484	2.836516e-04	-0.0755063814
4	-0.0041814717	3.963175e-05	-0.0239235676
5	-0.0045446370	5.483782e-05	-0.0259824724
6	-0.0020347195	4.528577e-05	-0.0116225720
7	0.0005818237	-4.136881e-06	0.0033233050
8	-0.0036894991	3.496886e-05	-0.0211008426
9	0.0084326716	-1.017528e-04	0.0483270417
10	-0.0035088364	4.509210e-05	-0.0200497965
11	-0.0035626546	2.533118e-05	-0.0203894917
12	0.0026831469	-1.907770e-05	0.0153425320
13	-0.0210228362	4.333390e-04	-0.1205368506
14	0.0109992656	-2.503349e-04	0.0630481121
15	-0.0031047015	2.942618e-05	-0.0177494005
16	-0.0047049813	6.554322e-05	-0.0268861764
17	-0.0048882674	6.281919e-05	-0.0279435780
18	0.0035090370	-1.215397e-04	0.0201329662
19	-0.0052515314	1.561332e-04	-0.0301456538
20	0.0099500184	-1.200618e-04	0.0570989433
21	0.0330494595	-6.714667e-04	0.1901782172
22	-0.0031409358	2.233267e-05	-0.0179678471
23	0.0002502676	1.604358e-06	0.0014294920
24	-0.0043090174	6.169595e-05	-0.0246196589
25	-0.0032354589	2.300475e-05	-0.0185103482
26	0.0056951899	-9.065767e-05	0.0325347387
27	0.0016382707	-2.565966e-05	0.0093572847
28	-0.0044531782	6.203545e-05	-0.0254459544
29	-0.0010174010	-6.522120e-06	-0.0058157422
30	-0.0136523908	3.038547e-04	-0.0783202143
31	-0.0026945387	3.251363e-05	-0.0153953469
32	0.0004942835	-5.995958e-05	0.0028329581
33	0.0052388134	-1.557551e-04	0.0300719129
34	-0.0048906986	5.901357e-05	-0.0279653053
35	0.0195328334	-4.347329e-04	0.1125765583
36	0.0008205447	3.777578e-05	0.0047039117

37	0.0116563281	-2.825172e-04	0.0670408900
38	-0.0011905019	1.436518e-05	-0.0068000913
39	0.0005050618	-6.126705e-05	0.0028951781
40	-0.0046856118	6.527339e-05	-0.0267753821
41	-0.0001584561	3.526681e-06	-0.0009050335
42	-0.0158922845	3.175631e-04	-0.0908826422
43	-0.0041814717	3.963175e-05	-0.0239235676
44	-0.0008578372	6.099392e-06	-0.0049001695
45	0.0004600663	-9.483243e-06	0.0026277054
46	-0.0029883964	4.455174e-05	-0.0170704159
47	-0.0176143407	3.630805e-04	-0.1008776691
48	0.0086962759	-6.183224e-05	0.0502769088
49	-0.0191291979	3.862813e-04	-0.1095006214
50	-0.0035626546	2.533118e-05	-0.0203894917
51	-0.0061977728	1.842659e-04	-0.0356482401
52	-0.0108685922	2.759329e-04	-0.0626082513
53	-0.0031059364	6.595622e-05	-0.0177420734
54	-0.0012296407	3.121824e-05	-0.0070239382
55	-0.0037831891	8.033804e-05	-0.0216121076
56	-0.0084822408	1.673828e-04	-0.0484598466
57	-0.0002686645	3.259064e-05	-0.0015360679
58	-0.0217198569	4.515883e-04	-0.1246406069
59	0.0043187599	-9.171117e-05	0.0246730867
60	0.0035234173	-1.220378e-04	0.0202162267
61	-0.0043090174	6.169595e-05	-0.0246196589
62	-0.0011453689	3.967123e-05	-0.0065449947
63	0.0052429082	-1.166889e-04	0.0299645876
64	-0.0142444449	2.783512e-04	-0.0814060023
65	0.0023432284	-5.215211e-05	0.0133852385
66	-0.0187178321	3.802906e-04	-0.1071631139
67	0.0045648717	-1.357182e-04	0.0261716841
68	-0.0002107169	1.498239e-06	-0.0012035328
69	0.0115729281	-2.575731e-04	0.0663085099
70	-0.0054498556	1.887623e-04	-0.0314709070
71	-0.0127214231	3.083322e-04	-0.0732649284
72	0.0061806584	-8.610029e-05	0.0353315365
73	0.0142257292	-1.348306e-04	0.0829027581
74	-0.0004831812	-2.224443e-05	-0.0027632454
75	-0.0169500658	3.772495e-04	-0.0974714823
76	-0.0202777480	4.362974e-04	-0.1165839499
77	-0.0031964327	4.576611e-05	-0.0182600781
78	0.0002548939	1.173466e-05	0.0014563605
79	-0.0135061422	3.273516e-04	-0.0778671954

80	-0.0132451498	3.014495e-04	-0.0760445031
81	-0.0146944827	3.120452e-04	-0.0841733272
82	0.0083281924	-1.731556e-04	0.0475998941
83	-0.0007982605	1.695149e-05	-0.0045593595
84	-0.0048267116	1.671790e-04	-0.0278060008
85	0.0289256082	-6.142507e-04	0.1671014356
86	-0.0217198569	4.515883e-04	-0.1246406069
87	-0.0001208482	1.465961e-05	-0.0006903756
88	0.0038312054	-7.965649e-05	0.0218853911
89	-0.0034535894	2.455570e-05	-0.0197628872
90	-0.0108474718	2.414270e-04	-0.0621280377
91	-0.0008698271	1.211722e-05	-0.0049681622
92	0.0013044868	-1.236385e-05	0.0074519029
93	0.0095161066	-1.475975e-04	0.0543936135
94	0.0005066016	-6.145384e-05	0.0029040691
95	0.0137062484	-3.119438e-04	0.0787209302
96	-0.0023286566	2.992560e-05	-0.0133028649
97	0.0035377975	-1.225359e-04	0.0202994966
98	0.0005058317	-6.136044e-05	0.0028996235
99	-0.0007064644	-3.252382e-05	-0.0040460545
100	-0.0049802294	6.400100e-05	-0.0284702013
101	-0.0038383084	5.495640e-05	-0.0219287066
102	-0.0036059566	3.417705e-05	-0.0206218213
103	-0.0013231821	9.408086e-06	-0.0075595490
104	-0.0030138576	4.493132e-05	-0.0172158905
105	-0.0002828210	2.680561e-06	-0.0016153644
106	0.0175078884	-2.610118e-04	0.1003984571
107	-0.0046430352	5.966771e-05	-0.0265394953
108	-0.0047049813	6.554322e-05	-0.0268861764
109	-0.0010109001	-6.480446e-06	-0.0057785209
110	0.0035377975	-1.225359e-04	0.0202994966
111	-0.0042876215	6.138961e-05	-0.0244973303
112	0.0052057024	-8.153510e-05	0.0297387507
113	0.0000000000	0.000000e+00	0.0000000000
114	0.0000000000	0.000000e+00	0.0000000000
115	0.0049393724	-7.862635e-05	0.0282156559
116	-0.0048906986	5.901357e-05	-0.0279653053
117	-0.0020861862	3.158151e-05	-0.0119159758
118	0.0079344685	-1.182890e-04	0.0453554092
119	-0.0021136873	3.199783e-05	-0.0120730735
120	-0.0047049813	6.554322e-05	-0.0268861764
121	-0.0042662256	6.108326e-05	-0.0243750029
122	0.0086983052	-1.296764e-04	0.0497299200

123	0.0037585367	-5.886865e-05	0.0214694090
124	0.0100532647	-1.559289e-04	0.0574691048
125	0.0287240754	-4.771200e-04	0.1644208905
126	-0.0005191546	-2.390055e-05	-0.0029695581
127	0.0359418142	-5.358293e-04	0.2088215441
128	0.0002409940	-2.923403e-05	0.0013775880
129	-0.0006965407	-3.206695e-05	-0.0039889150
130	-0.0020586851	3.116519e-05	-0.0117588788
131	-0.0007536020	-3.469391e-05	-0.0043176509
132	-0.0040607992	3.848802e-05	-0.0232309012
133	-0.0006035060	-2.778388e-05	-0.0034538378
134	-0.0138229602	3.076510e-04	-0.0793075341
135	-0.0200247421	4.001388e-04	-0.1145985204
136	-0.0006761056	-4.334222e-06	-0.0038630277
137	0.0011669893	-2.510902e-05	0.0066654853
138	0.0128432240	-2.647345e-04	0.0734602567
139	-0.0106034304	2.281441e-04	-0.0606709944
140	0.0071002195	-1.580262e-04	0.0406015026
141	0.0112443470	-1.823052e-04	0.0642585133
142	0.0052592359	-1.563623e-04	0.0301903281
143	-0.0032535612	3.925907e-05	-0.0185922770
144	0.0049733212	-1.478618e-04	0.0285337620
145	-0.0110854415	2.814383e-04	-0.0638795483
146	-0.0021671940	4.376276e-05	-0.0123784314
147	0.0135260085	-2.812260e-04	0.0773956841
148	-0.0081242929	2.415433e-04	-0.0469681403
149	-0.0029629352	4.417216e-05	-0.0169249421
150	-0.0004114048	1.223147e-05	-0.0023498390
151	-0.0029374739	4.379257e-05	-0.0167794692
152	0.0075783612	-1.836786e-04	0.0434113462
153	0.0004604251	-1.594738e-05	0.0026299539
154	0.0038224927	2.450436e-05	0.0220904326
155	0.0035282107	-1.222038e-04	0.0202439823
156	0.0045719274	-4.333246e-05	0.0261662392
157	0.0044645454	-3.174380e-05	0.0255806674
158	0.0064077146	-1.553053e-04	0.0366747860
159	-0.0035771966	2.543457e-05	-0.0204730564
160	0.0018521544	-1.755461e-05	0.0105822470
161	-0.0023617872	2.849848e-05	-0.0134930815
162	-0.0043090174	6.169595e-05	-0.0246196589
163	0.0093200779	-2.366191e-04	0.0535663068
164	-0.0220234954	4.539654e-04	-0.1263218669
165	-0.0041460467	1.436033e-04	-0.0238307036

166	0.0113324552	-1.837337e-04	0.0647625945
167	-0.0007139072	-3.286646e-05	-0.0040889179
168	-0.0005298361	-3.396552e-06	-0.0030268713
169	0.0096955586	-1.937388e-04	0.0554024299
170	0.0030887385	-7.486250e-05	0.0176501121
171	0.0009071708	-1.352432e-05	0.0051814245
172	-0.0015797258	-1.012694e-05	-0.0090406599
173	0.0001455628	-1.034980e-06	0.0008313949
174	0.0176748976	-2.813541e-04	0.1011391598
175	0.0112882396	-1.796894e-04	0.0645223941
176	0.0123016458	-1.994472e-04	0.0703083864
177	-0.0017836741	2.700196e-05	-0.0101879401
178	0.0049393724	-7.862635e-05	0.0282156559
179	0.0049393724	-7.862635e-05	0.0282156559
180	0.0191409337	-3.145998e-04	0.1094598647
181	0.0016046157	-2.513254e-05	0.0091650504
182	-0.0048906986	5.901357e-05	-0.0279653053
183	-0.0021136873	3.199783e-05	-0.0120730735
184	0.0002264324	-3.512029e-06	0.0012932847
185	-0.0042876215	6.138961e-05	-0.0244973303
186	0.0003212250	-4.982289e-06	0.0018347003
187	0.0069800797	-1.111109e-04	0.0398787470
188	-0.0047049813	6.554322e-05	-0.0268861764
189	0.0049393724	-7.862635e-05	0.0282156559
190	-0.0030138576	4.493132e-05	-0.0172158905
191	0.0191409337	-3.145998e-04	0.1094598647
192	-0.0043090174	6.169595e-05	-0.0246196589
193	0.0049771633	-7.922792e-05	0.0284315957
194	-0.0048116323	6.183435e-05	-0.0275047641
195	-0.0047975282	5.788933e-05	-0.0274313743
196	0.0088318326	-1.405877e-04	0.0504670015
197	-0.0048374583	5.837115e-05	-0.0276601935
198	0.0102854734	-1.321788e-04	0.0589698138
199	0.0197457407	-3.245404e-04	0.1129274941
200	0.0016046157	-2.513254e-05	0.0091650504
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203	-0.0007461592	-3.435126e-05	-0.0042747467
204	-0.0001493336	1.811507e-05	-0.0008531989
205	-0.0058525025	2.027085e-04	-0.0338536812
206	-0.0029654640	2.810650e-05	-0.0169519886
207	-0.0007647661	-3.520788e-05	-0.0043820222
208	0.0112443470	-1.823052e-04	0.0642585133

209	0.0114646176	-1.858764e-04	0.0655187413
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211	0.0034850700	-1.207096e-04	0.0199942193
212	-0.0041629067	3.945579e-05	-0.0238169903
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214	-0.0010336532	-6.626306e-06	-0.0059088008
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227	-0.0064100180	1.458871e-04	-0.0366556459
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274	0.0000000000	0.000000e+00	0.0000000000
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2	-0.0255757136		
3	0.0918071912		

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7	-0.0013353098
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12	-0.0061646562
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20	-0.0389349171
21	-0.2183489171
22	0.0072195123
23	0.0005178555
24	0.0199200594
25	0.0074374902
26	-0.0292667062
27	-0.0082821918
28	0.0200317462
29	-0.0021068421
30	0.0985056841
31	0.0104978572
32	-0.0194201603
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36	0.0122377212
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39	-0.0198466838
40	0.0210783079
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45	-0.0030608592
46	0.0143813856

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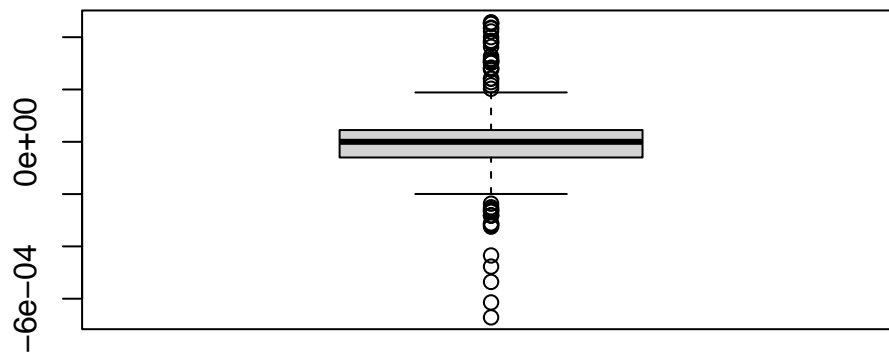
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285	0.0000000000
286	0.0000000000
287	0.0000000000
288	0.0000000000
289	0.0000000000
290	0.0000000000

```
boxplot(dfb[, "post_scaled"])
```




```
leverage <- cut(dfb[, "post_scaled"], quantile(dfb[, "post_scaled"], probs=c(0, .05, .95, 1), na.rm=T),
summary(leverage)
```

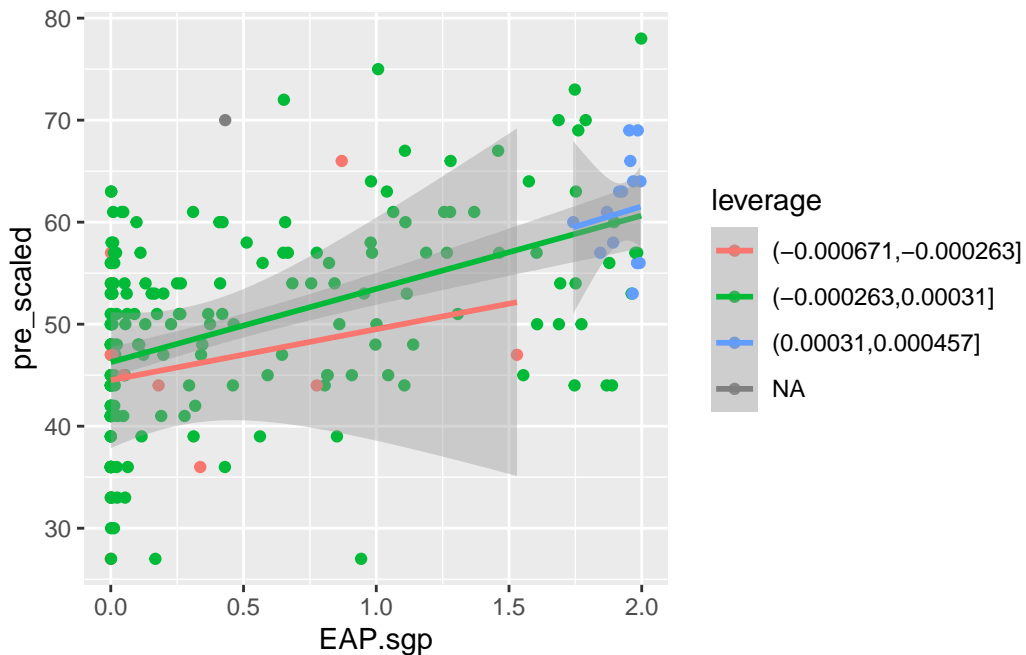
```
(-0.000671,-0.000263]    (-0.000263,0.00031]    (0.00031,0.000457]
      14                      260                      15
NA's
      1
```

```
ggplot(ACEDextract, aes(y=pre_scaled, x=EAP.sgp, color=leverage)) + scale_color_discrete() +
```

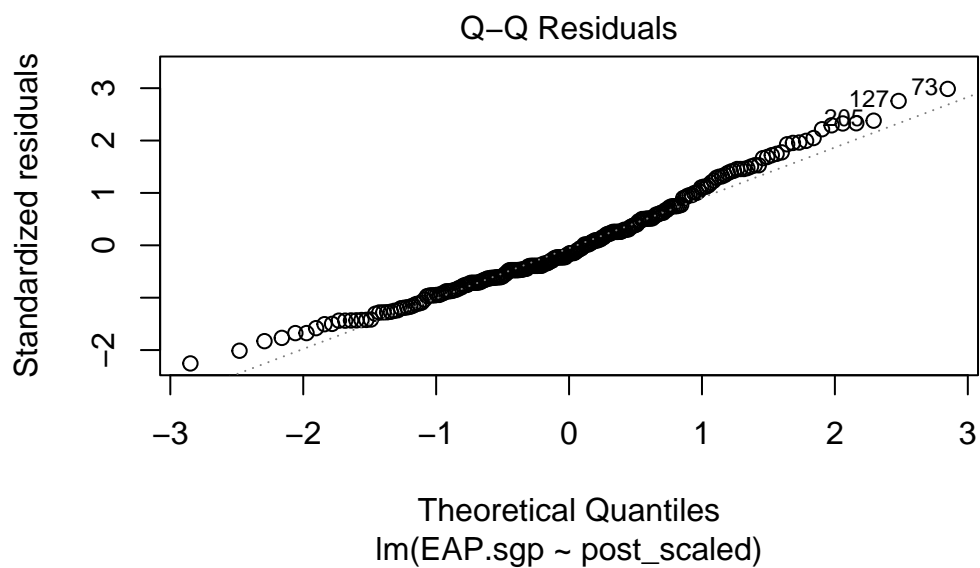
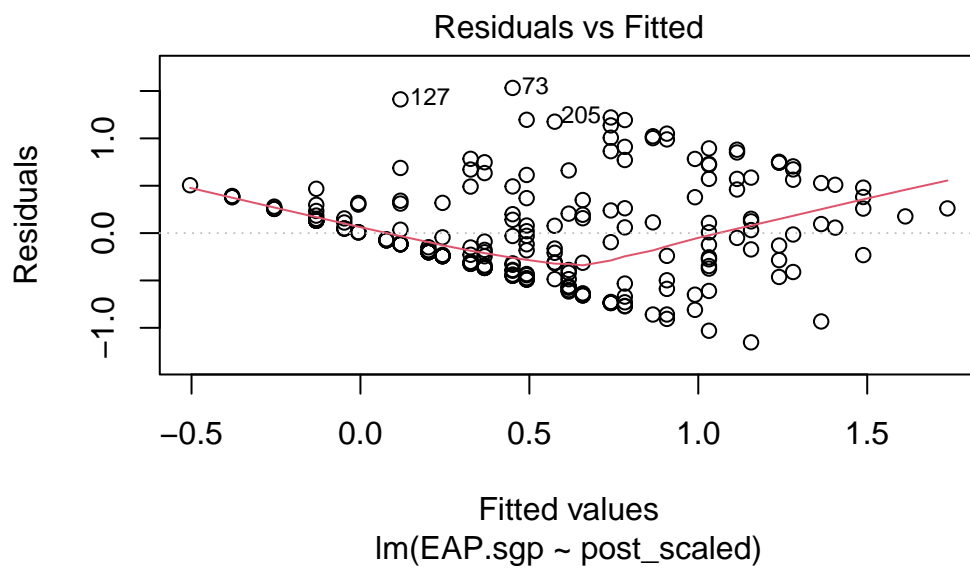
```
`geom_smooth()` using formula = 'y ~ x'
```

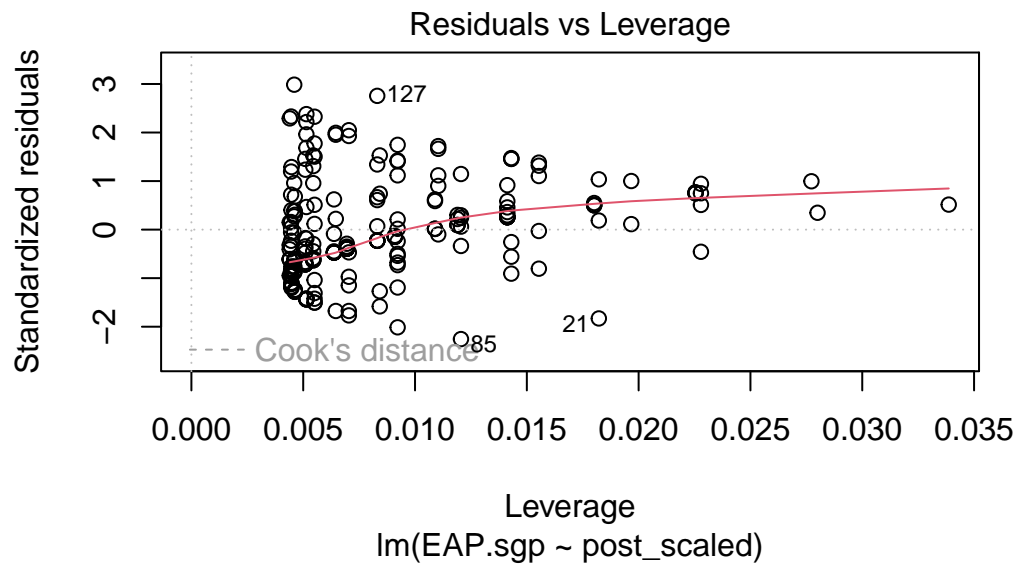
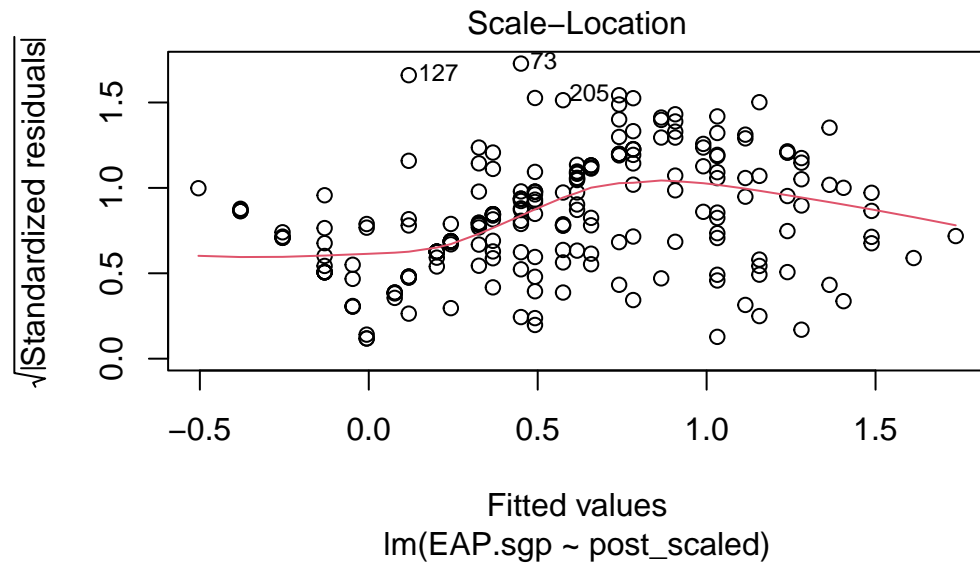
Warning: Removed 62 rows containing non-finite values (`stat_smooth()`).

Warning: Removed 62 rows containing missing values (`geom_point()`).



```
plot(lm_PostxEAP)
```





Five Assumptions

0. Representative Sample

Missing Data

1. Independent Observations

Time Series

Clusters

2. Linear form

Transformations

3. Homoscedasticity – Equal variances

Weighted regression

Transforming Y

4. Normality of Residuals

5. Subgroup differences

Color plots by group

Do the groups mix?

Are the slopes similar?

Analysis of Covariance (look ahead)

Outliers and influential points.

Sensitivity Analysis

Assignment

For the regression `post_scaled ~ EAP.sgp`; answer the following questions?

0. Are there problems with the sample? Non-representative group? Missing data?

Sample is a single middle school in a wealthy NJ district, so low generalizability to all middle schools.

Most missing data is because control students did not get internal ACED measure (EAP.sgp)

1. Is the distribution the same for everybody in the group? Are there clusters? Serial (time) dependencies?

Grouped by classrooms. (Might want to color by class.)

2. Is the relationship mostly linear? Will transforming X or Y make it more linear?
3. Is the variance roughly the same for all values of \hat{Y} ? Will transforming Y help?
4. Are the residuals roughly normal? Are there any outliers? Will transforming Y help?
5. Are there any differences by subgroup?

In the ACED data set, pay attention to `Level_Code` and `Condition_code`.