Bilingualism

R Markdown

We load the data and remove the cases with NA values.

```
str(D1)
```

```
## 'data.frame':    104 obs. of  16 variables:
##  $ Name  : Factor w/ 104 levels "Albert Denk",..: 1 2 3 4 5 6 7 8 9 10 ...
##  $ CoR   : Factor w/ 2 levels "0","1": 1 2 2 2 2 2 2 2 1 1 2 ...
##  $ Hand  : Factor w/ 2 levels "0","1": 2 2 2 1 2 2 2 2 2 2 2 ...
##  $ EO    : Factor w/ 2 levels "0","1": 1 1 2 2 2 2 2 2 1 1 2 ...
##  $ List  : Factor w/ 2 levels "0","1": 1 1 2 1 1 2 2 2 2 2 2 ...
##  $ CEF   : Ord.factor w/ 3 levels "3"<"4"<"5": 2 3 2 3 2 3 1 3 3 3 ...
##  $ SRRC  : num  3.8 4 4 4 4 5 3 5 3.5 5 ...
##  $ PRE   : num  0.33 0.5 1 1 0.78 1 0.83 1 0.88 1 ...
##  $ POST1 : num  0.94 1 1 1 0.94 1 1 1 1 1 ...
##  $ POST2 : num  1 0.88 1 1 0.88 1 1 0.88 0.88 1 ...
##  $ STAY  : Factor w/ 2 levels "0","1": 1 1 2 2 1 2 1 2 1 2 2 ...
##  $ LEAYRS: num  4.2 5 4 3.08 5 5 1.5 7 15 10 ...
##  $ HRSD  : num  0.25 0.75 0.5 0.125 0 1.5 0 4 1 0.125 ...
##  $ RPV   : num  5 5 3.5 5 5 2.5 3 2.5 4 2.5 ...
##  $ AMGE  : num  3.5 4 4.5 4 4.5 5 4.5 5 5 4.5 ...
##  $ AMSP  : num  4.1 3.67 4.17 4.33 3.33 ...
```

```
L0 <- read.csv2("size.csv",na.strings="#NUM!",sep=";",dec=",",header=TRUE)
L0$Median <- apply(L0[c(3:10,15:21)],1,median,na.rm = TRUE)
LM<-L0 %>% select(Name,MEDIAN.2)
names(LM)[2]<-"time"
#LMM<-L0 %>% select(Name, Median)
#LMM<-L0 %>% select(Name, MISMATCH.RTdominantanswerMedian)
LMM<-L0 %>% select(Name, MEDIAN)#MISMATCH.RTdominantanswerMedian)
names(LMM)[2]<-"time"

SM<-left_join(D1,LM,by="Name")
```

```
## Warning in left_join_impl(x, y, by$x, by$y): joining factors with
## different levels, coercing to character vector
```

```
SMM<-left_join(D1,LMM,by="Name")
```

```
## Warning in left_join_impl(x, y, by$x, by$y): joining factors with
## different levels, coercing to character vector
```

```
S<-rbind(data.frame(SM,type="MATCH"),data.frame(SMM,type="MISMATCH"))
S<-na.omit(S)
```

In total we have 225 data points.

Multiple Linear Regression

We try first a first order multiple linear regression model

```
S<-S%>%select(-Name)
m<-lm(data=S,time~.)
print(anova(m),signif.stars=TRUE)
```

```
## Analysis of Variance Table
##
## Response: time
##            Df   Sum Sq Mean Sq F value  Pr(>F)
## CoR         1   265064  265064    1.05 0.3079
## Hand        1   190551  190551    0.75 0.3871
## EO          1   109484  109484    0.43 0.5119
## List        1   645364  645364    2.55 0.1124
## CEF         2   184786   92393    0.36 0.6950
## SRRC        1    86284   86284    0.34 0.5603
## PRE         1    34840   34840    0.14 0.7112
## POST1       1    26649   26649    0.11 0.7461
## POST2       1     7823    7823    0.03 0.8607
## STAY        1     2148    2148    0.01 0.9268
## LEAYRS      1   151380  151380    0.60 0.4407
## HRSD        1   325238  325238    1.28 0.2589
## RPV         1   391744  391744    1.55 0.2155
## AMGE        1    42644   42644    0.17 0.6822
## AMSP        1  1527954 1527954    6.03 0.0151 *
## type        1  2127585 2127585    8.40 0.0043 **
## Residuals 162 41042709  253350
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

and then we include all second order terms:

```
library(MASS)
m2<-lm(data=S,time~.^2)
print(anova(m2),signif.stars=TRUE)
```

```
## Analysis of Variance Table
##
## Response: time
##            Df  Sum Sq Mean Sq F value   Pr(>F)
## CoR         1  265064  265064    2.14 0.14747
## Hand        1  190551  190551    1.54 0.21845
## EO          1  109484  109484    0.89 0.34984
## List        1  645364  645364    5.22 0.02525 *
## CEF         2  184786   92393    0.75 0.47730
## SRRC        1   86284   86284    0.70 0.40627
## PRE         1   34840   34840    0.28 0.59717
## POST1       1   26649   26649    0.22 0.64387
## POST2       1    7823    7823    0.06 0.80212
## STAY        1    2148    2148    0.02 0.89552
## LEAYRS      1  151380  151380    1.22 0.27218
```

```
## HRSD         1  325238  325238   2.63 0.10917
## RPV          1  391744  391744   3.17 0.07926 .
## AMGE         1   42644   42644   0.34 0.55886
## AMSP         1 1527954 1527954  12.36 0.00076 ***
## type         1 2127585 2127585  17.21 9.0e-05 ***
## CoR:Hand     1    8497    8497   0.07 0.79396
## CoR:List     1  189080  189080   1.53 0.22022
## CoR:CEF      2  320950  160475   1.30 0.27938
## CoR:SRRC     1  667877  667877   5.40 0.02291 *
## CoR:PRE      1   16205   16205   0.13 0.71840
## CoR:POST1    1  150303  150303   1.22 0.27388
## CoR:POST2    1 2412616 2412616  19.51 3.4e-05 ***
## CoR:STAY     1   48687   48687   0.39 0.53231
## CoR:LEAYRS   1  359744  359744   2.91 0.09233 .
## CoR:HRSD     1  589420  589420   4.77 0.03223 *
## CoR:RPV      1    1792    1792   0.01 0.90452
## CoR:AMGE     1  432223  432223   3.50 0.06556 .
## CoR:AMSP     1    4014    4014   0.03 0.85752
## CoR:type     1    3125    3125   0.03 0.87413
## Hand:EO      1   49992   49992   0.40 0.52688
## Hand:List    1  308767  308767   2.50 0.11839
## Hand:CEF     2  343779  171889   1.39 0.25558
## Hand:SRRC    1  104725  104725   0.85 0.36047
## Hand:PRE     1   32416   32416   0.26 0.61020
## Hand:POST1   1  299611  299611   2.42 0.12390
## Hand:POST2   1  355519  355519   2.87 0.09423 .
## Hand:STAY    1   13816   13816   0.11 0.73914
## Hand:type    1   16110   16110   0.13 0.71918
## EO:List      1  142357  142357   1.15 0.28683
## EO:CEF       2  271920  135960   1.10 0.33850
## EO:SRRC      1    1589    1589   0.01 0.91006
## EO:PRE       1 2395189 2395189  19.37 3.6e-05 ***
## EO:POST1     1  382122  382122   3.09 0.08296 .
## EO:POST2     1    1838    1838   0.01 0.90330
## EO:STAY      1  226299  226299   1.83 0.18030
## EO:LEAYRS    1  115103  115103   0.93 0.33784
## EO:HRSD      1  178378  178378   1.44 0.23362
## EO:RPV       1  138280  138280   1.12 0.29379
## EO:AMGE      1  174389  174389   1.41 0.23887
## EO:AMSP      1 2038880 2038880  16.49 0.00012 ***
## EO:type      1  119955  119955   0.97 0.32792
## List:CEF     2  956743  478372   3.87 0.02530 *
## List:SRRC    1 1102451 1102451   8.92 0.00385 **
## List:PRE     1 1207811 1207811   9.77 0.00255 **
## List:POST1   1    1564    1564   0.01 0.91077
## List:POST2   1 1954975 1954975  15.81 0.00016 ***
## List:STAY    1    9643    9643   0.08 0.78084
## List:LEAYRS  1  116857  116857   0.94 0.33421
## List:HRSD    1  163409  163409   1.32 0.25409
## List:RPV     1  249751  249751   2.02 0.15953
## List:AMGE    1  614911  614911   4.97 0.02883 *
## List:AMSP    1  824213  824213   6.67 0.01184 *
## List:type    1  700247  700247   5.66 0.01994 *
## CEF:SRRC     2 2687913 1343957  10.87 7.4e-05 ***
```

3

```
## CEF:PRE       2  393642   196821      1.59 0.21058
## CEF:POST1     2  368807   184403      1.49 0.23187
## CEF:POST2     2 1069933   534967      4.33 0.01677 *
## CEF:STAY      2  253097   126549      1.02 0.36448
## CEF:LEAYRS    2  523401   261701      2.12 0.12781
## CEF:HRSD      2   33323    16661      0.13 0.87416
## CEF:RPV       1  474671   474671      3.84 0.05391 .
## CEF:AMGE      1  700911   700911      5.67 0.01989 *
## CEF:AMSP      1  143020   143020      1.16 0.28572
## CEF:type      2  242689   121344      0.98 0.37972
## SRRC:PRE      1 1758019 1758019     14.22 0.00033 ***
## SRRC:POST1    1   41020    41020      0.33 0.56642
## SRRC:POST2    1  433635   433635      3.51 0.06513 .
## SRRC:STAY     1   64828    64828      0.52 0.47135
## SRRC:LEAYRS   1  600141   600141      4.85 0.03075 *
## SRRC:HRSD     1  254111   254111      2.05 0.15598
## SRRC:RPV      1    9715     9715      0.08 0.78005
## SRRC:AMGE     1  163893   163893      1.33 0.25339
## SRRC:type     1    2242     2242      0.02 0.89325
## PRE:type      1   56469    56469      0.46 0.50133
## POST1:type    1   70118    70118      0.57 0.45387
## POST2:type    1   32899    32899      0.27 0.60756
## STAY:type     1  125910   125910      1.02 0.31628
## LEAYRS:type   1    4651     4651      0.04 0.84676
## HRSD:type     1   91631    91631      0.74 0.39216
## RPV:type      1  150728   150728      1.22 0.27320
## AMGE:type     1   25592    25592      0.21 0.65051
## AMSP:type     1  420386   420386      3.40 0.06927 .
## Residuals    73 9027171   123660
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We apply stepwise model search procedure:

```
model.stp<-stepAIC(aov(data=S,time~.^2),scope=list(upper=~.^2,lower=~1),
                   direction="backward",trace=FALSE)
print(model.stp$anova,signif.stars=TRUE)
```

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## time ~ (CoR + Hand + EO + List + CEF + SRRC + PRE + POST1 + POST2 +
##     STAY + LEAYRS + HRSD + RPV + AMGE + AMSP + type)^2
##
## Final Model:
## time ~ CoR + Hand + EO + List + CEF + SRRC + PRE + POST1 + POST2 +
##     STAY + LEAYRS + HRSD + RPV + AMGE + AMSP + type + CoR:Hand +
##     CoR:List + CoR:CEF + CoR:SRRC + CoR:POST1 + CoR:POST2 + CoR:STAY +
##     CoR:LEAYRS + CoR:HRSD + CoR:RPV + CoR:AMGE + CoR:AMSP + Hand:EO +
##     Hand:List + Hand:CEF + Hand:SRRC + Hand:PRE + Hand:POST1 +
##     Hand:POST2 + EO:List + EO:CEF + EO:PRE + EO:POST1 + EO:POST2 +
##     EO:STAY + EO:HRSD + EO:RPV + List:CEF + List:SRRC + List:PRE +
```

```
##      List:POST1 + List:POST2 + List:STAY + List:LEAYRS + List:HRSD +
##      List:RPV + List:AMGE + List:AMSP + List:type + CEF:SRRC +
##      CEF:POST1 + CEF:POST2 + CEF:STAY + CEF:LEAYRS + CEF:HRSD +
##      CEF:RPV + CEF:AMGE + CEF:AMSP + CEF:type + SRRC:PRE + SRRC:POST2 +
##      SRRC:LEAYRS + SRRC:AMGE + POST2:type + STAY:type + AMSP:type
##
##
##              Step Df   Deviance Resid. Df Resid. Dev    AIC
## 1                                      73    9027171 2162.1
## 2       - AMGE:AMSP  0 0.0000e+00       73    9027171 2162.1
## 3        - RPV:AMSP  0 0.0000e+00       73    9027171 2162.1
## 4        - RPV:AMGE  0 0.0000e+00       73    9027171 2162.1
## 5       - HRSD:AMSP  0 0.0000e+00       73    9027171 2162.1
## 6       - HRSD:AMGE  0 0.0000e+00       73    9027171 2162.1
## 7        - HRSD:RPV  0 0.0000e+00       73    9027171 2162.1
## 8     - LEAYRS:AMSP  0 0.0000e+00       73    9027171 2162.1
## 9     - LEAYRS:AMGE  0 0.0000e+00       73    9027171 2162.1
## 10     - LEAYRS:RPV  0 0.0000e+00       73    9027171 2162.1
## 11    - LEAYRS:HRSD  0 0.0000e+00       73    9027171 2162.1
## 12      - STAY:AMSP  0 0.0000e+00       73    9027171 2162.1
## 13      - STAY:AMGE  0 0.0000e+00       73    9027171 2162.1
## 14       - STAY:RPV  0 0.0000e+00       73    9027171 2162.1
## 15      - STAY:HRSD  0 0.0000e+00       73    9027171 2162.1
## 16    - STAY:LEAYRS  0 0.0000e+00       73    9027171 2162.1
## 17     - POST2:AMSP  0 0.0000e+00       73    9027171 2162.1
## 18     - POST2:AMGE  0 0.0000e+00       73    9027171 2162.1
## 19      - POST2:RPV  0 0.0000e+00       73    9027171 2162.1
## 20     - POST2:HRSD  0 0.0000e+00       73    9027171 2162.1
## 21   - POST2:LEAYRS  0 0.0000e+00       73    9027171 2162.1
## 22     - POST2:STAY  0 0.0000e+00       73    9027171 2162.1
## 23     - POST1:AMSP  0 0.0000e+00       73    9027171 2162.1
## 24     - POST1:AMGE  0 0.0000e+00       73    9027171 2162.1
## 25      - POST1:RPV  0 0.0000e+00       73    9027171 2162.1
## 26     - POST1:HRSD  0 0.0000e+00       73    9027171 2162.1
## 27   - POST1:LEAYRS  0 0.0000e+00       73    9027171 2162.1
## 28     - POST1:STAY  0 0.0000e+00       73    9027171 2162.1
## 29    - POST1:POST2  0 0.0000e+00       73    9027171 2162.1
## 30      - PRE:AMSP  0 0.0000e+00       73    9027171 2162.1
## 31      - PRE:AMGE  0 0.0000e+00       73    9027171 2162.1
## 32       - PRE:RPV  0 0.0000e+00       73    9027171 2162.1
## 33      - PRE:HRSD  0 0.0000e+00       73    9027171 2162.1
## 34    - PRE:LEAYRS  0 0.0000e+00       73    9027171 2162.1
## 35      - PRE:STAY  0 0.0000e+00       73    9027171 2162.1
## 36     - PRE:POST2  0 0.0000e+00       73    9027171 2162.1
## 37     - PRE:POST1  0 0.0000e+00       73    9027171 2162.1
## 38     - SRRC:AMSP  0 0.0000e+00       73    9027171 2162.1
## 39       - EO:AMSP  0 2.4214e-07       73    9027171 2162.1
## 40       - EO:AMGE  0 7.5065e-07       73    9027171 2162.1
## 41     - Hand:AMSP  0 0.0000e+00       73    9027171 2162.1
## 42     - Hand:AMGE  0 0.0000e+00       73    9027171 2162.1
## 43      - Hand:RPV  0 0.0000e+00       73    9027171 2162.1
## 44     - Hand:HRSD  0 0.0000e+00       73    9027171 2162.1
## 45   - Hand:LEAYRS  0 0.0000e+00       73    9027171 2162.1
## 46     - Hand:STAY  0 2.1048e-07       73    9027171 2162.1
```
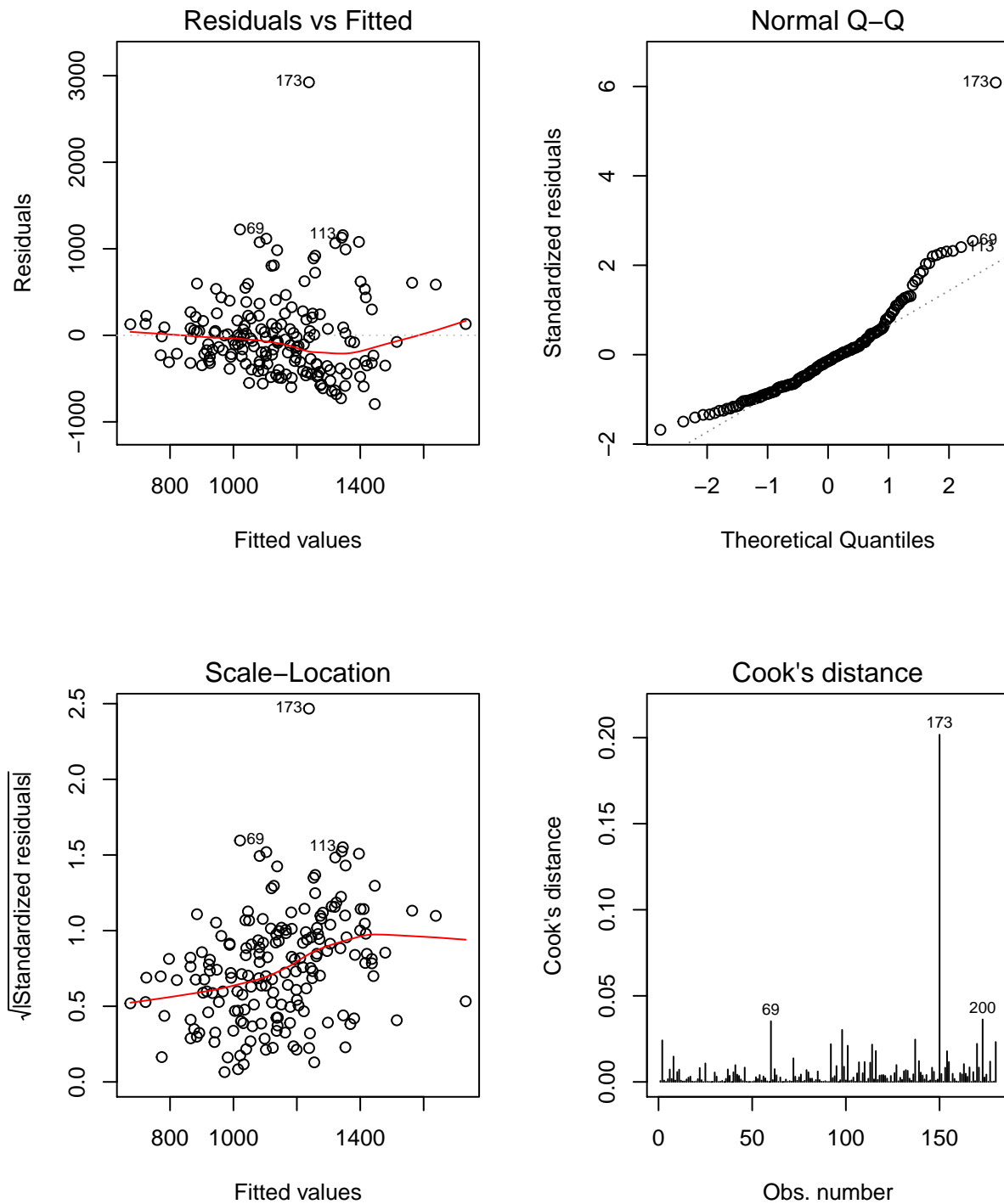
```
## 47        - CoR:EO  0 0.0000e+00      73    9027171 2162.1
## 48        - CEF:PRE  2 6.5659e+04      75    9092831 2159.4
## 49      - SRRC:STAY  1 1.2638e+03      76    9094094 2157.4
## 50     - Hand:type  1 3.3329e+03      77    9097427 2155.5
## 51        - EO:SRRC  1 3.8371e+03      78    9101264 2153.6
## 52    - SRRC:POST1  1 2.6644e+03      79    9103929 2151.6
## 53       - PRE:type  1 4.4195e+03      80    9108348 2149.7
## 54   - LEAYRS:type  1 1.1728e+04      81    9120076 2147.9
## 55     - EO:LEAYRS  1 1.2560e+04      82    9132636 2146.2
## 56     - SRRC:HRSD  1 8.5993e+03      83    9141235 2144.4
## 57      - SRRC:RPV  1 9.0195e+03      84    9150254 2142.5
## 58       - CoR:PRE  1 1.9209e+04      85    9169463 2140.9
## 59    - POST1:type  1 2.8320e+04      86    9197784 2139.5
## 60     - SRRC:type  1 3.8608e+04      87    9236392 2138.2
## 61      - CoR:type  1 7.8630e+04      88    9315022 2137.8
## 62       - EO:type  1 2.2847e+04      89    9337868 2136.2
## 63     - HRSD:type  1 8.6711e+04      90    9424579 2135.9
## 64     - AMGE:type  1 9.0477e+04      91    9515056 2135.6
## 65      - RPV:type  1 9.5362e+04      92    9610418 2135.4
```

```r
#m2b<-lm(data=D1,)
#print(anova(m2b),signif.stars = TRUE)
#anova(m2b,m2)
```

Diagnostic plots

```r
par(mfrow=c(2,2))
plot(m,which=1:4)
```

From the qplot we see that the point 1071 is an outlier: With hindsight we already remove it above. Afterwards the qqplot looks perfectly normal.
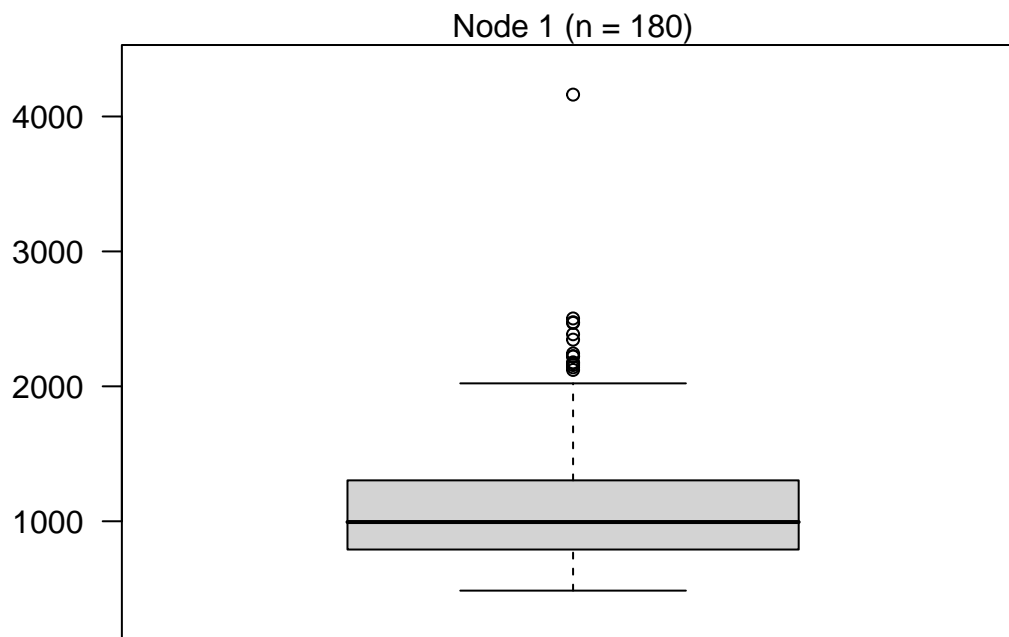
Regression tree

Another type of analysis by means of regression tree:

```
ct <- ctree(data=S,time~.^2)
ct
```

```
##
##    Conditional inference tree with 1 terminal nodes
##
## Response:  time
## Inputs:  CoR, Hand, EO, List, CEF, SRRC, PRE, POST1, POST2, STAY, LEAYRS, HRSD, RPV, AMGE, AMSP, typ
## Number of observations:  180
##
## 1)*  weights = 180
```
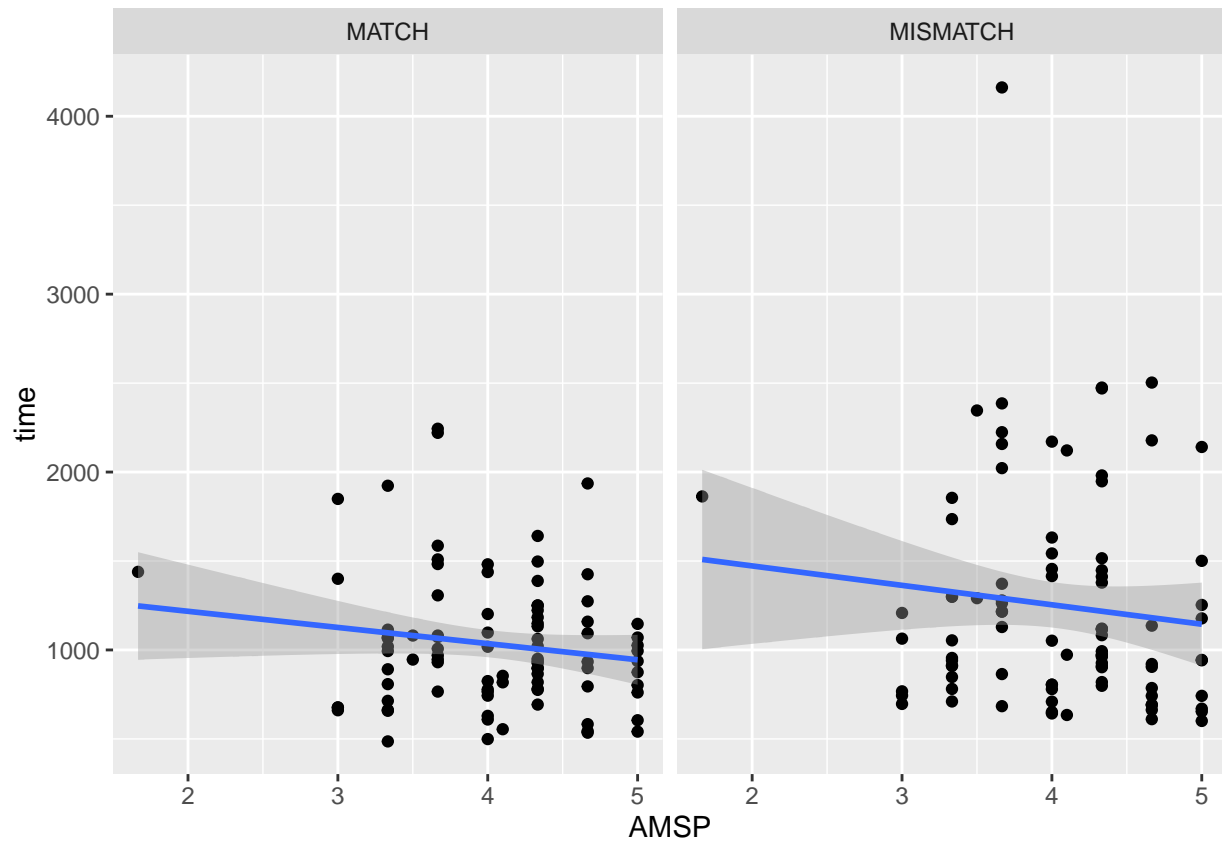
```
plot(ct)
```

Node 1 (n = 180)

From the plot we understand that regression trees find only two factors POST1 and Hand and their interaction as relevant expalin differences in the response time.

Data visualization

We visualize the influence of the two factors that have been found explaning the most the reponse time. We separate the plots in match and mismatch cases, although this factor was found not to be important.

```
q<-ggplot(data=S,aes(y=time,x=AMSP))
q<-q+facet_grid(.~type)
q<-q+geom_point()
q<-q+geom_smooth(method=lm)
q<-q+theme(legend.position="top")
print(q)
```

We shall conclude that the response time depends on the hand and on the general proficency in the verbs as assessed by the POST1 test. Right handed subjects with good performance in the POST1 test respond faster.