

# Multiclass logistic regression

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For a similar analysis, look at this tutorial from UCLA. For more about `glmnet`, consult this tutorial by Trevor Hastie.

First, we import the data.

```
data<-read.csv("hsbdemo.csv")
#View(data)
data

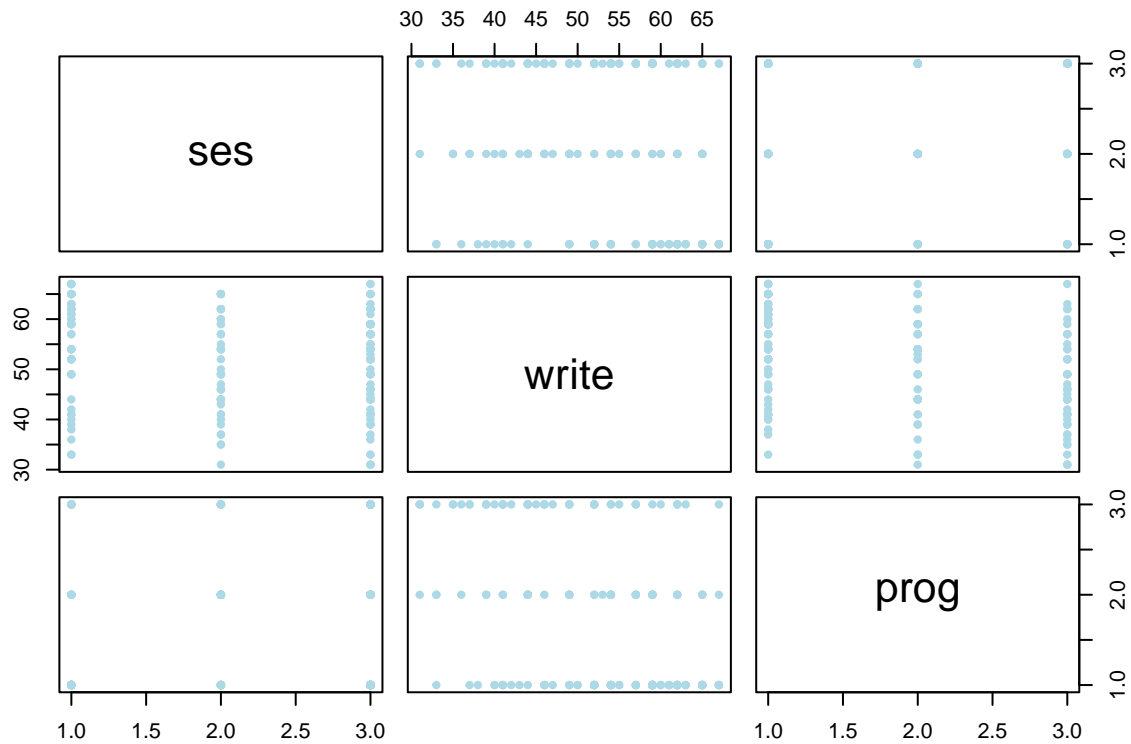
##      X id female      ses schtyp      prog read write math science socst
## 1 1 45 female      low public vocation   34   35  41      29   26
## 2 2 108  male middle public  general   34   33  41      36   36
## 3 3 15  male  high public vocation   39   39  44      26   42
## 4 4 67  male  low public vocation   37   37  42      33   32
## 5 5 153  male middle public vocation   39   31  40      39   51
## 6 6 51 female  high public  general   42   36  42      31   39
## 7 7 164  male middle public vocation   31   36  46      39   46
##      honors awards cid
## 1 not enrolled      0  1
## 2 not enrolled      0  1
## 3 not enrolled      0  1
## 4 not enrolled      0  1
## 5 not enrolled      0  1
## 6 not enrolled      0  1
## 7 not enrolled      0  1
## [ reached 'max' / getOption("max.print") -- omitted 193 rows ]
```

The data set contains variables on 200 students. We will focus on a small subset of predictors. The predictor variables will be socio-economic status `ses` (a three-level categorical variable) and writing score `write` (a quantitative variable). The outcome variable is program type `prog` (a three-level categorical variable). Since I am interested in just this subset, I will create a smaller data frame to analyze.

```
df=data.frame(data$ses, data$write, data$prog)
colnames(df)<-c("ses", "write", "prog")
attach(df)
```

Some exploratory data analysis is called for. The first idea is, probably to try the `plot` command.

```
plot(df,
      pch=20, col="lightblue")
```

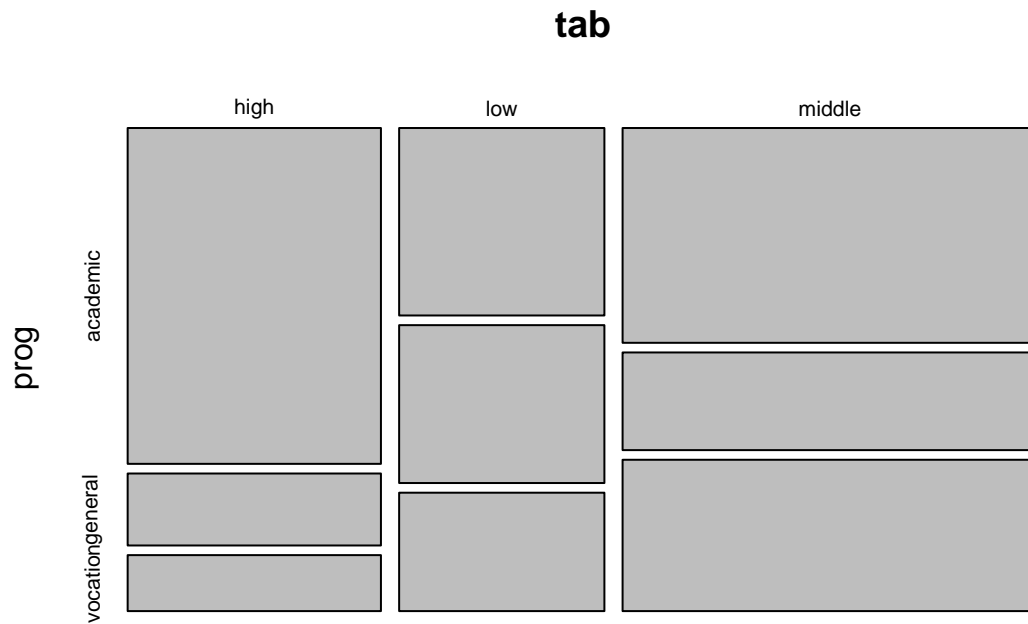


As we can see, this is not too useful. To look at the *association* between `ses` and `prog`, a two-way table might do the trick.

```
tab=table(ses, prog)
tab
```

```
##          prog
## ses      academic general vocation
##  high         42         9         7
##  low          19        16        12
##  middle       44        20        31
```

```
mosaicplot(tab)
```



Which test might

we use to test the independence hypothesis?

```
chi2<-chisq.test(tab)
chi2
```

```
##
## Pearson's Chi-squared test
##
## data:  tab
## X-squared = 16.604, df = 4, p-value = 0.002307
```

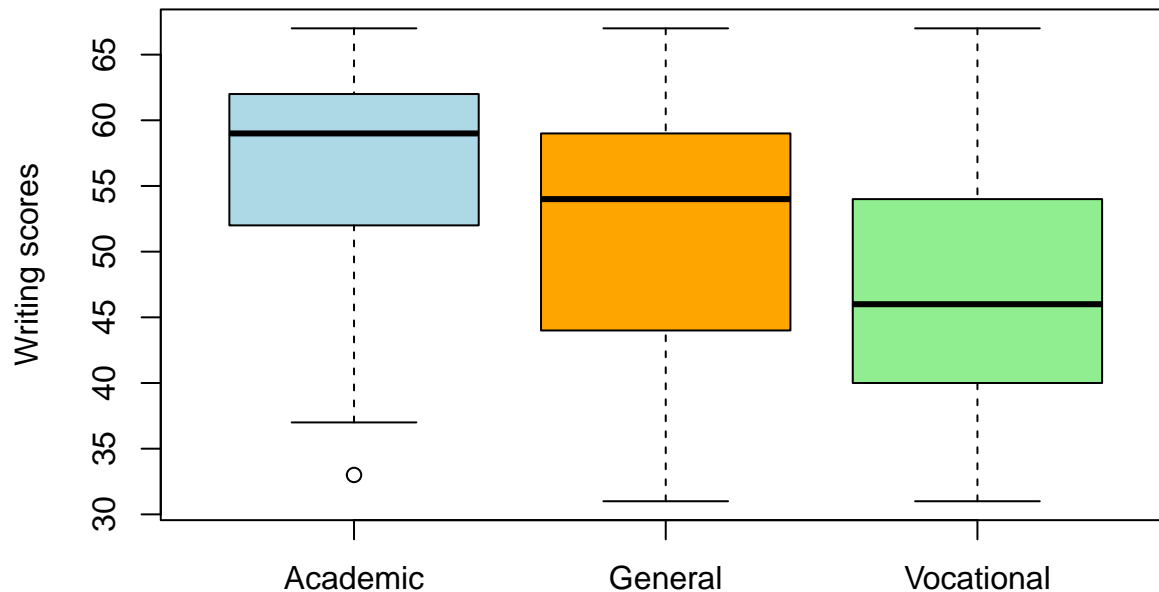
What about the association between the writing score and the program type?

Side-by-side boxplots might give insight.

```
write.ac=write[which(prog=="academic")]
write.gen=write[which(prog=="general")]
write.voc=write[which(prog=="vocation")]

boxplot(write.ac,write.gen, write.voc,
  main = "Writing scores by program type",
  ylab = "Writing scores",
  names = c("Academic", "General", "Vocational"),
  col=c("lightblue", "orange", "lightgreen")
)
```

## Writing scores by program type



We see that there is an association, but we will learn more about the extent of the effect if we run a multiclass logistic regression.

### multinom

Our first option is the `multinom` implementation in the `nnet` package.

```
#install.packages("nnet")
library(nnet)
```

This implementation requires of us to set a *baseline* level for the response variable.

```
df$prog<-as.factor(df$prog)
df$prog.base <- relevel(df$prog, ref = "academic")
```

Now, we can run the `multinom` function.

```
mn.fit<-multinom(prog.base ~ ses + write, data=df)
```

```
## # weights:  15 (8 variable)
## initial  value 219.722458
## iter   10 value 179.983731
## final   value 179.981726
## converged
```

Here is what the object `mn.fit` looks like:

```
summary(mn.fit)
```

```
## Call:
## multinom(formula = prog.base ~ ses + write, data = df)
##
## Coefficients:
##          (Intercept)      seslow sesmiddle      write
## general      1.689478  1.1628411  0.6295638 -0.05793086
## vocation      4.235574  0.9827182  1.2740985 -0.11360389
```

```
##
## Std. Errors:
##      (Intercept)      seslow sesmiddle      write
## general      1.226939 0.5142211 0.4650289 0.02141101
## vocation      1.204690 0.5955688 0.5111119 0.02222000
##
## Residual Deviance: 359.9635
## AIC: 375.9635
```

Importantly, the coefficients above are **different** from the coefficients one sees in our textbook. However, let us look at the fitted probabilities for our data set.

```
fitted.ps <- fitted(mn.fit)
fitted.ps
```

```
##      academic      general      vocation
## 1  0.1482721 0.33825094 0.51347695
## 2  0.1201988 0.18063349 0.69916776
## 3  0.4186768 0.23681368 0.34450947
## 4  0.1726839 0.35084330 0.47647284
## 5  0.1001206 0.16894278 0.73093666
## 6  0.3533583 0.23780466 0.40883700
## 7  0.1562526 0.19735515 0.64639223
## 8  0.1001206 0.16894278 0.73093666
## 9  0.2331247 0.22040133 0.54647393
## 10 0.1699365 0.20255764 0.62750590
## 11 0.2777676 0.37620933 0.34602312
## 12 0.2917517 0.23361220 0.47463615
## 13 0.1071652 0.30822610 0.58460873
## 14 0.2888732 0.22953872 0.48158807
## 15 0.1482721 0.33825094 0.51347695
## 16 0.2777676 0.37620933 0.34602312
## 17 0.3126201 0.37709158 0.31028831
## 18 0.3293850 0.23309576 0.43751925
## 19 0.3293850 0.23309576 0.43751925
## 20 0.6324633 0.20043456 0.16710218
## 21 0.1998541 0.21215684 0.58798906
## 22 0.2888732 0.22953872 0.48158807
## 23 0.3306561 0.37639804 0.29294591
## 24 0.2777676 0.37620933 0.34602312
## 25 0.1726839 0.35084330 0.47647284
## 26 0.3966353 0.23772687 0.36563784
## 27 0.3676891 0.37276358 0.25954735
## 28 0.2888732 0.22953872 0.48158807
## 29 0.2291956 0.36934430 0.40146013
## 30 0.3865745 0.36985112 0.24357436
## 31 0.2888732 0.22953872 0.48158807
## 32 0.1996861 0.36131931 0.43899458
## 33 0.2141360 0.36565697 0.42020707
## [ reached 'max' / getOption("max.print") -- omitted 167 rows ]
```

Also importantly, we do not have  $p$ -values reported above. We can figure them out easily, though.

```
z.scores<- summary(mn.fit)$coefficients/summary(mn.fit)$standard.errors
p.val=2*(1-pnorm(abs(z.scores)))
p.val
```

```
##          (Intercept)      seslow sesmiddle      write
## general  0.1685163893 0.02373673 0.1757949 0.0068169138868
## vocation 0.0004382601 0.09893276 0.0126741 0.0000003176088
```

How well did we do on the training set?

```
pred.mn.tr=predict(mn.fit, newdata = df, "class")
#pred.mn.tr
ind.tr=(pred.mn.tr==prog)
mean(ind.tr)
```

```
## [1] 0.61
```

How would we predict for a test case? First, we need to define what the inputs for the test case would be.

```
new.data <- data.frame(ses = c("low", "middle", "high"), write = c(quantile(df$write, 0.25), median(df$write, 0.25)))
```

Now, we can use the `predict` command to see what the predicted probabilities would be.

```
pred.mn=predict(mn.fit, newdata = new.data, "probs")
pred.mn
```

```
##      academic    general    vocation
## 25% 0.3081702 0.3771467 0.31468315
##      0.5049235 0.2247935 0.27028295
## 75% 0.8043171 0.1347768 0.06090615
```

## glmnet

Here, we need to install and load a package create by Hastie et al.

```
#install.packages("glmnet")
library(glmnet)
```

```
## Loading required package: Matrix
```

```
## Loaded glmnet 4.1-10
```

We notice that we need to transform our categorical predictor using dummy variables. For that, the following library is useful:

```
library(caret)
```

```
## Loading required package: ggplot2
```

```
## Loading required package: lattice
```

First, I will put all of my predictors into a separate data frame.

```
temp.x=data.frame(data$ses, data$write)
```

Now, I will use the command `dummyVars` to create dummy variables for my one categorical predictor `ses` in my array of predictors.

```
dummy.x <- dummyVars(" ~ .", data = temp.x)
x <- as.matrix(predict(dummy.x, newdata = temp.x))
print(x)
```

```
##      data.seshigh data.seslow data.sesmiddle data.write
## 1              0           1              0           35
## 2              0           0              1           33
## 3              1           0              0           39
```

```
## 4      0      1      0      37
## 5      0      0      1      31
## 6      1      0      0      36
## 7      0      0      1      36
## 8      0      0      1      31
## 9      0      0      1      41
## 10     0      0      1      37
## 11     0      1      0      44
## 12     1      0      0      33
## 13     0      1      0      31
## 14     0      0      1      44
## 15     0      1      0      35
## 16     0      1      0      44
## 17     0      1      0      46
## 18     0      0      1      46
## 19     0      0      1      46
## 20     1      0      0      49
## 21     0      0      1      39
## 22     0      0      1      44
## 23     0      1      0      47
## 24     0      1      0      44
## 25     0      1      0      37
## [ reached 'max' / getOption("max.print") -- omitted 175 rows ]
```

Now, we would like to fit the model using `glmnet`.

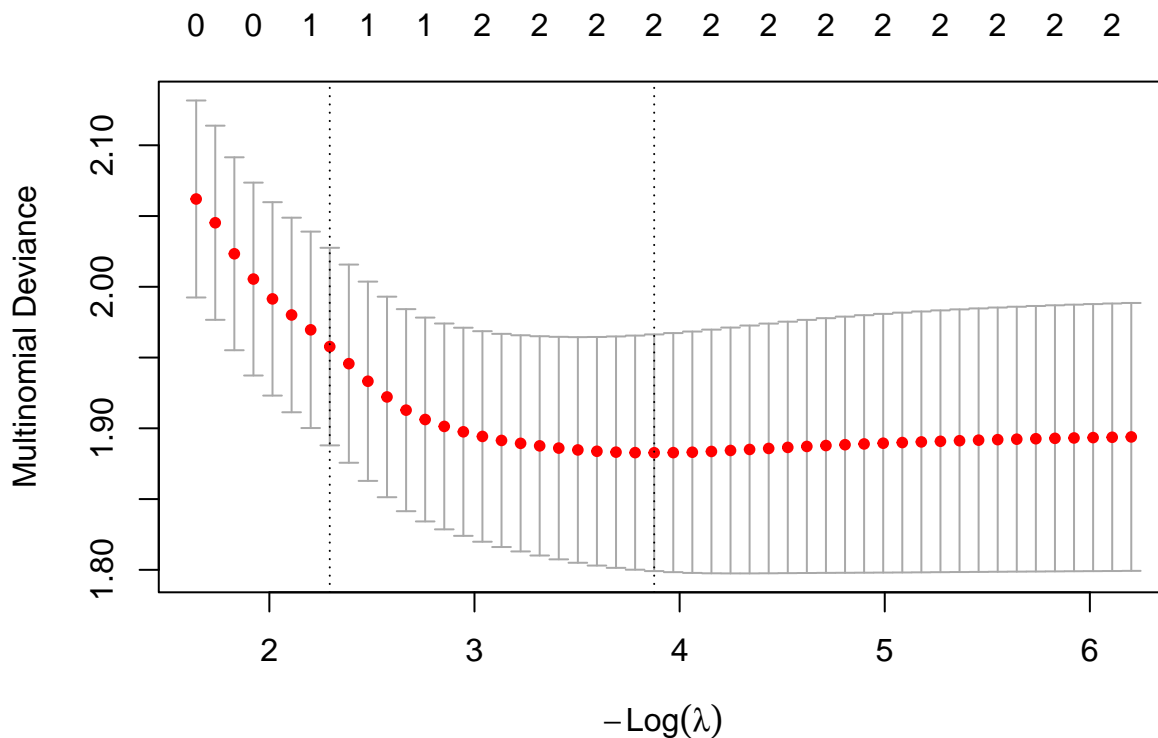
```
y <- df$prog
#y
glm.fit <- glmnet(x, y, family = "multinomial")
#summary(glm.fit)
#glm.fit
predict(glm.fit, newx=x, s=0, type="response")
```

```
## , , s=0
##
##      academic    general    vocation
## 1  0.1526166 0.33690080 0.51048259
## 2  0.1240333 0.18489797 0.69106876
## 3  0.4172688 0.23461004 0.34812117
## 4  0.1771834 0.34881146 0.47400509
## 5  0.1037572 0.17343832 0.72280443
## 6  0.3528570 0.23557453 0.41156851
## 7  0.1602391 0.20117013 0.63859078
## 8  0.1037572 0.17343832 0.72280443
## 9  0.2368129 0.22328970 0.53989743
## 10 0.1739242 0.20620006 0.61987571
## 11 0.2822784 0.37220402 0.34551754
## 12 0.2921047 0.23156195 0.47633332
## 13 0.1110538 0.30824709 0.58069910
## 14 0.2919886 0.23186238 0.47614904
## 15 0.1526166 0.33690080 0.51048259
## 16 0.2822784 0.37220402 0.34551754
## 17 0.3169693 0.37272452 0.31030614
## 18 0.3319611 0.23508177 0.43295716
## 19 0.3319611 0.23508177 0.43295716
```

```
## 20 0.6288569 0.19944323 0.17169987
## 21 0.2037564 0.21543051 0.58081312
## 22 0.2919886 0.23186238 0.47614904
## 23 0.3348986 0.37189274 0.29320866
## 24 0.2822784 0.37220402 0.34551754
## 25 0.1771834 0.34881146 0.47400509
## 26 0.3955289 0.23549149 0.36897962
## 27 0.3716716 0.36807063 0.26025772
## 28 0.2919886 0.23186238 0.47614904
## 29 0.2338110 0.36607265 0.40011633
## 30 0.3904065 0.36510890 0.24448463
## 31 0.2919886 0.23186238 0.47614904
## 32 0.2042785 0.35863911 0.43708236
## 33 0.2187490 0.36267251 0.41857853
##
## [ reached 'max' / getOption("max.print") -- omitted 167 rows ]
```

What if I try to find, by cross-validation, an optimal tuning parameter?

```
cv.fit <- cv.glmnet(x, y, family = "multinomial")
plot(cv.fit)
```



Now, we can try to predict at the optimal  $\lambda$ :

```
predict(cv.fit, newx = x, s = "lambda.min", type = "class")
```

```
##      lambda.min
## [1,] "vocation"
## [2,] "vocation"
## [3,] "academic"
## [4,] "vocation"
## [5,] "vocation"
```



```
## [6,] "vocation"
## [7,] "vocation"
## [8,] "vocation"
## [9,] "vocation"
## [10,] "vocation"
## [11,] "vocation"
## [12,] "vocation"
## [13,] "vocation"
## [14,] "vocation"
## [15,] "vocation"
## [16,] "vocation"
## [17,] "academic"
## [18,] "vocation"
## [19,] "vocation"
## [20,] "academic"
## [21,] "vocation"
## [22,] "vocation"
## [23,] "academic"
## [24,] "vocation"
## [25,] "vocation"
## [26,] "vocation"
## [27,] "academic"
## [28,] "vocation"
## [29,] "vocation"
## [30,] "academic"
## [31,] "vocation"
## [32,] "vocation"
## [33,] "vocation"
## [34,] "academic"
## [35,] "vocation"
## [36,] "vocation"
## [37,] "vocation"
## [38,] "academic"
## [39,] "vocation"
## [40,] "vocation"
## [41,] "vocation"
## [42,] "academic"
## [43,] "academic"
## [44,] "academic"
## [45,] "vocation"
## [46,] "academic"
## [47,] "vocation"
## [48,] "academic"
## [49,] "vocation"
## [50,] "academic"
## [51,] "vocation"
## [52,] "vocation"
## [53,] "vocation"
## [54,] "academic"
## [55,] "academic"
## [56,] "academic"
## [57,] "academic"
## [58,] "academic"
## [59,] "academic"
```

```
## [60,] "vocation"
## [61,] "academic"
## [62,] "vocation"
## [63,] "academic"
## [64,] "academic"
## [65,] "academic"
## [66,] "vocation"
## [67,] "academic"
## [68,] "academic"
## [69,] "academic"
## [70,] "academic"
## [71,] "academic"
## [72,] "academic"
## [73,] "academic"
## [74,] "academic"
## [75,] "academic"
## [76,] "academic"
## [77,] "academic"
## [78,] "academic"
## [79,] "vocation"
## [80,] "vocation"
## [81,] "academic"
## [82,] "academic"
## [83,] "academic"
## [84,] "vocation"
## [85,] "academic"
## [86,] "academic"
## [87,] "academic"
## [88,] "vocation"
## [89,] "academic"
## [90,] "vocation"
## [91,] "academic"
## [92,] "academic"
## [93,] "academic"
## [94,] "academic"
## [95,] "academic"
## [96,] "academic"
## [97,] "academic"
## [98,] "academic"
## [99,] "vocation"
## [100,] "vocation"
## [ reached 'max' / getOption("max.print") -- omitted 100 rows ]
```

We might want to see how well we did on the training data.

```
preds=predict(cv.fit, newx = x, s = "lambda.min", type = "class")
#preds
ind=(preds==y)
mean(ind)
```

```
## [1] 0.59
```