R Examples Repository

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Binary logistic regression

- Binary logistic regression
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Binary logistic regression

TODO

- link to associationOrder for `pROC` , regressionOrdinal, regressionMultinom, regressionDiag for outliers, collinearity, crossvalidation

Install required packages

`rms` (http://cran.r-project.org/package=rms)

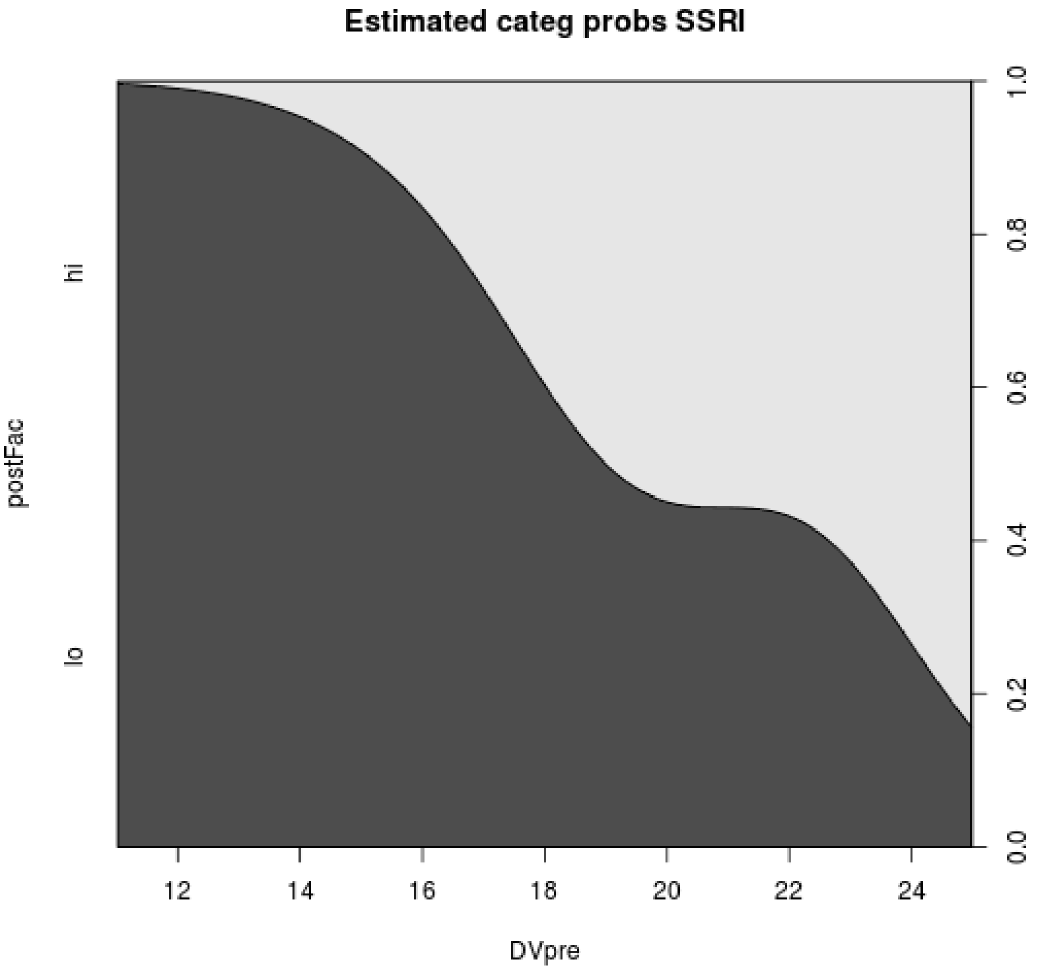
```
wants <- c("rms")
has   <- wants %in% rownames(installed.packages())
if(any(!has)) install.packages(wants[!has])
```

Descriptive model fit

Simulate data

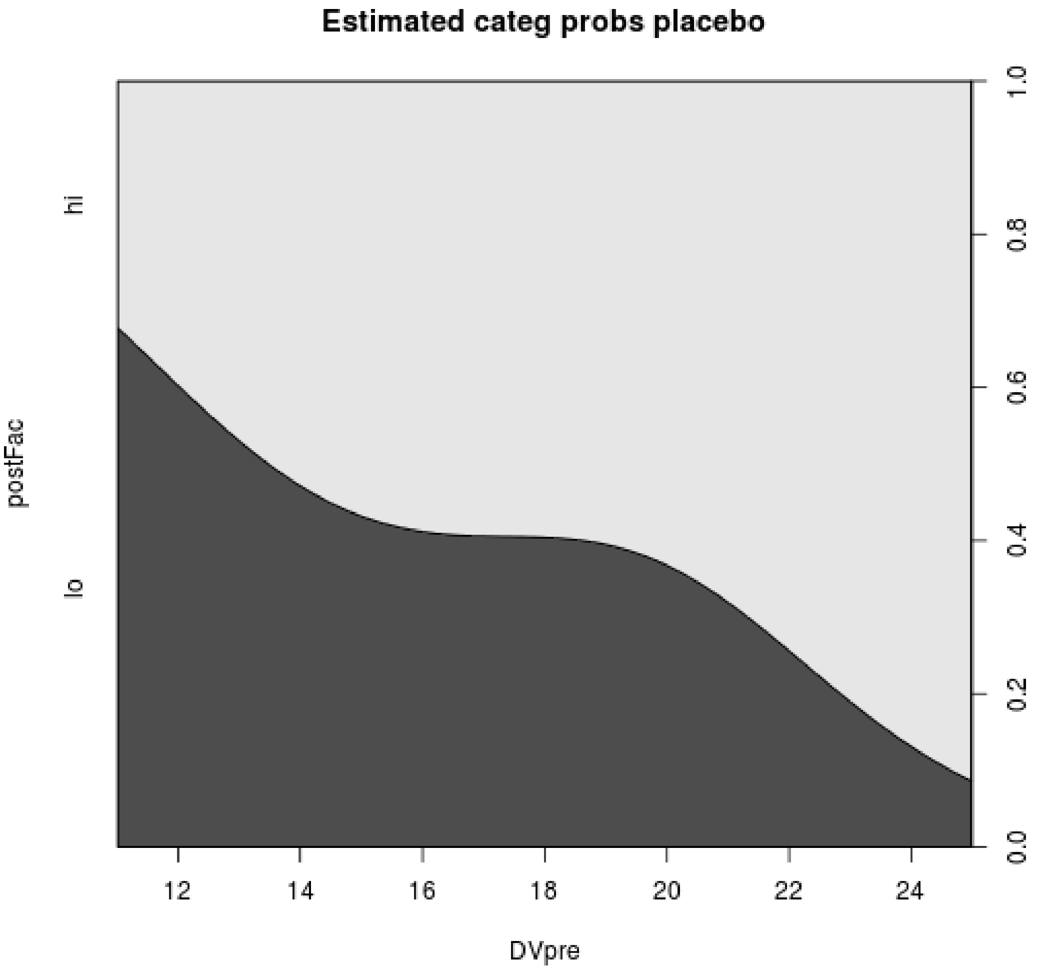
```
set.seed(123)
SSRIpre  <- c(18, 16, 16, 15, 14, 20, 14, 21, 25, 11)
SSRIpost <- c(12,  0, 10,  9,  0, 11,  2,  4, 15, 10)
PlacPre  <- c(18, 16, 15, 14, 20, 25, 11, 25, 11, 22)
PlacPost <- c(11,  4, 19, 15,  3, 14, 10, 16, 10, 20)
WLpre    <- c(15, 19, 10, 29, 24, 15,  9, 18, 22, 13)
WLpost   <- c(17, 25, 10, 22, 23, 10,  2, 10, 14,  7)

P        <- 3
Nj       <- rep(length(SSRIpre), times=P)
IV       <- factor(rep(1:P, Nj), labels=c("SSRI", "Placebo", "WL"))
DVpre    <- c(SSRIpre,  PlacPre,  WLpre)
DVpost   <- c(SSRIpost, PlacPost, WLpost)
postFac  <- cut(DVpost, breaks=c(-Inf, median(DVpost), Inf),
                        labels=c("lo", "hi"))
dfAncova <- data.frame(IV, DVpre, DVpost, postFac)
```

```
cdplot(postFac ~ DVpre, data=dfAncova, subset=IV == "SSRI",
       main="Estimated categ probs SSRI")
```



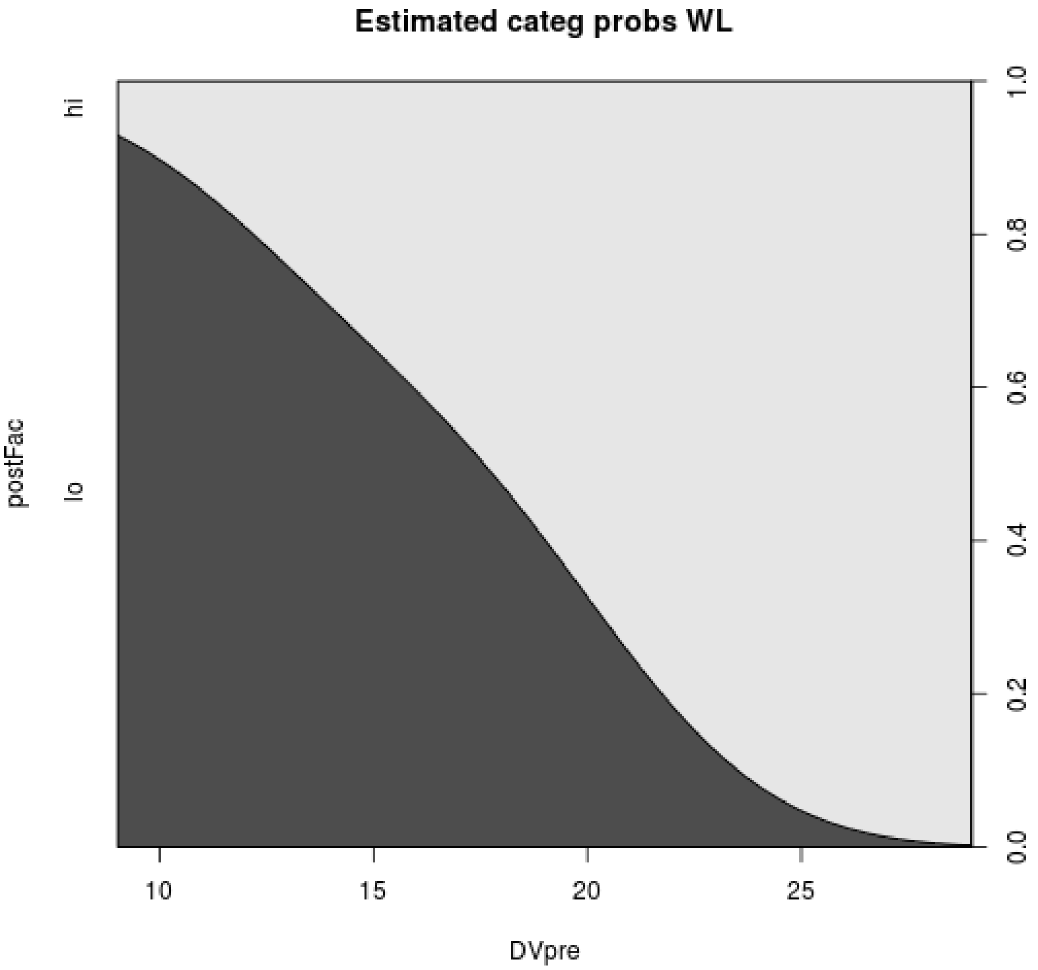
plot of chunk rerRegressionLogistic01

```
cdplot(postFac ~ DVpre, data=dfAncova, subset=IV == "Placebo",
       main="Estimated categ probs placebo")
```



plot of chunk rerRegressionLogistic01

```
cdplot(postFac ~ DVpre, data=dfAncova, subset=IV == "WL",
       main="Estimated categ probs WL")
```



plot of chunk rerRegressionLogistic01

Fit the model

```
(glmFit <- glm(postFac ~ DVpre + IV, family=binomial(link="logit"), data=dfAnco
va))
```

```


Call:  glm(formula = postFac ~ DVpre + IV, family = binomial(link = "logit"),
    data = dfAncova)

Coefficients:
(Intercept)        DVpre    IVPlacebo         IVWL
    -8.4230       0.4258       1.7306       1.2027

Degrees of Freedom: 29 Total (i.e. Null);  26 Residual
Null Deviance:      41.46
Residual Deviance: 24.41    AIC: 32.41
```

Odds ratios

```
exp(coef(glmFit))
```

```
 (Intercept)        DVpre    IVPlacebo         IVWL
0.0002197532 1.5308001795 5.6440022784 3.3291484767
```

Profile likelihood based confidence intervals for odds ratios

```
exp(confint(glmFit))
```

```
                   2.5 %     97.5 %
(Intercept) 1.488482e-07  0.0251596
DVpre       1.193766e+00  2.2446549
IVPlacebo   5.343091e-01 95.1942030
IVWL        2.916673e-01 52.2883653
```

Fit the model based on a matrix of counts

```
N      <- 100
x1     <- rnorm(N, 100, 15)
x2     <- rnorm(N, 10, 3)
total  <- sample(40:60, N, replace=TRUE)
hits   <- rbinom(N, total, prob=0.4)
hitMat <- cbind(hits, total-hits)
glm(hitMat ~ x1 + x2, family=binomial(link="logit"))
```

```

Call:  glm(formula = hitMat ~ x1 + x2, family = binomial(link = "logit"))

Coefficients:
(Intercept)           x1           x2  
  -0.102410    -0.003373     0.005638  

Degrees of Freedom: 99 Total (i.e. Null);  97 Residual
Null Deviance:      99.35 
Residual Deviance: 96.44    AIC: 532.5
```

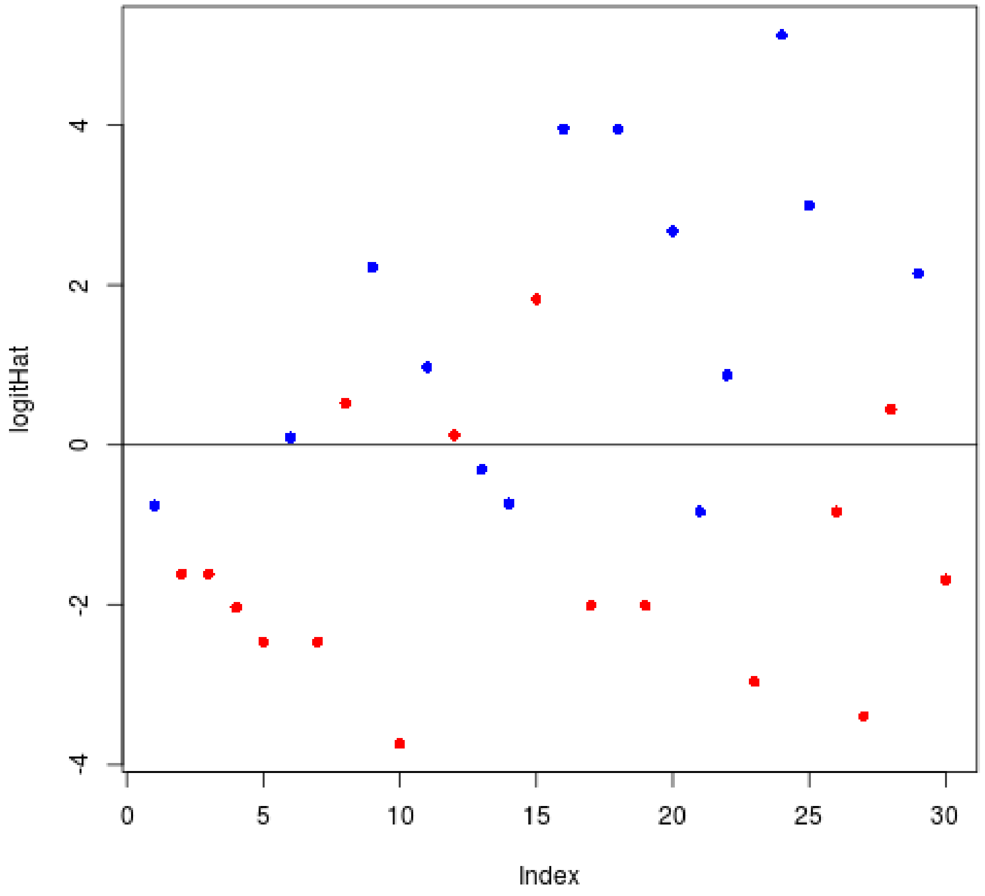
Fit the model based on relative frequencies

```
relHits <- hits/total
glm(relHits ~ x1 + x2, weights=total, family=binomial(link="logit"))
```

```

Call:  glm(formula = relHits ~ x1 + x2, family = binomial(link = "logit"), 
    weights = total)

Coefficients:
(Intercept)           x1           x2  
  -0.102410    -0.003373     0.005638  

Degrees of Freedom: 99 Total (i.e. Null);  97 Residual
Null Deviance:      99.35 
Residual Deviance: 96.44    AIC: 532.5
```

Fitted logits and probabilities

```
logitHat <- predict(glmFit, type="link")
plot(logitHat, pch=16, col=c("red", "blue")[unclass(dfAncova$postFac)])
abline(h=0)
```



plot of chunk rerRegressionLogistic02

```
Phat <- fitted(glmFit)
Phat <- predict(glmFit, type="response")
head(Phat)
```

```
         1          2          3          4          5          6 
0.31891231 0.16653918 0.16653918 0.11545968 0.07856997 0.52318493 
```

```
mean(Phat)
```

```
[1] 0.4666667
```

```
prop.table(xtabs(~ postFac, data=dfAncova))
```

```
postFac
       lo        hi 
0.5333333 0.4666667 
```

Assess model fit

Classification table

```
thresh <- 0.5
facHat <- cut(Phat, breaks=c(-Inf, thresh, Inf), labels=c("lo", "hi"))
cTab   <- xtabs(~ postFac + facHat, data=dfAncova)
addmargins(cTab)
```

```
       facHat
postFac lo hi Sum
    lo  12  4  16
    hi   4 10  14
    Sum 16 14  30
```

Correct classification rate

```
(CCR <- sum(diag(cTab)) / sum(cTab))
```

```
[1] 0.7333333
```

log-Likelihood, AUC, Somers' D_{xy}, Nagelkerke's pseudo R^2

Deviance, log-likelihood and AIC

```
deviance(glmFit)
```

```
[1] 24.40857
```

```
logLik(glmFit)
```

```
'log Lik.' -12.20428 (df=4)
```

```
AIC(glmFit)
```

```
[1] 32.40857
```

Nagelkerke's pseudo-R^2 (R2), area under the ROC-Kurve (C), Somers' D_{xy} (Dxy), Goodman & Kruskal's γ (Gamma), Kendall's τ (Tau-a)

```
library(rms)
lrm(postFac ~ DVpre + IV, data=dfAncova)
```

```
Logistic Regression Model

lrm(formula = postFac ~ DVpre + IV, data = dfAncova)

                     Model Likelihood     Discrimination    Rank Discrim.
                        Ratio Test           Indexes           Indexes
Obs            30    LR chi2     17.05    R2       0.579    C       0.900
 lo            16    d.f.            3    g        2.686    Dxy     0.799
 hi            14    Pr(> chi2) 0.0007    gr      14.672    gamma   0.803
max |deriv| 2e-06                         gp       0.404    tau-a   0.411
                                          Brier    0.139

           Coef    S.E.   Wald Z Pr(>|Z|)
Intercept  -8.4230 2.9502 -2.86  0.0043
DVpre       0.4258 0.1553  2.74  0.0061
IV=Placebo  1.7306 1.2733  1.36  0.1741
IV=WL       1.2027 1.2735  0.94  0.3450
```

For plotting the ROC-curve, see `pROC` in associationOrder

McFadden, Cox & Snell and Nagelkerke pseudo R^2

Log-likelihoods for full model and 0-model without predictors X1, X2

```
N    <- nobs(glmFit)
glm0 <- update(glmFit, . ~ 1)
LLf  <- logLik(glmFit)
LL0  <- logLik(glm0)
```

McFadden pseudo-R^2

```
as.vector(1 - (LLf / LL0))
```

```
[1] 0.411209
```

Cox & Snell

```
as.vector(1 - exp((2/N) * (LL0 - LLf)))
```

```
[1] 0.4334714
```

Nagelkerke

```
as.vector((1 - exp((2/N) * (LL0 - LLf))) / (1 - exp(LL0)^(2/N)))
```

```
[1] 0.578822
```

Crossvalidation

`cv.glm()` function from package `boot`, see crossvalidation

Apply model to new data

```
Nnew  <- 3
dfNew <- data.frame(DVpre=rnorm(Nnew, 20, sd=7),
                    IV=factor(rep("SSRI", Nnew), levels=levels(dfAncova$IV)))
predict(glmFit, newdata=dfNew, type="response")
```

```
         1          2          3 
0.11516886 0.10427434 0.06270597 
```

Coefficient tests and overall model test

Individual coefficient tests

Wald-tests for parameters

```
summary(glmFit)
```

```


Call:
glm(formula = postFac ~ DVpre + IV, family = binomial(link = "logit"), 
    data = dfAncova)

Deviance Residuals: 
    Min       1Q   Median       3Q      Max  
-1.9865  -0.5629  -0.2372   0.4660   1.5455  

Coefficients:
            Estimate Std. Error z value Pr(>|z|)   
(Intercept)  -8.4230     2.9502  -2.855   0.0043 **
DVpre         0.4258     0.1553   2.742   0.0061 **
IVPlacebo     1.7306     1.2733   1.359   0.1741   
IVWL          1.2027     1.2735   0.944   0.3450   
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 41.455  on 29  degrees of freedom
Residual deviance: 24.409  on 26  degrees of freedom
AIC: 32.409

Number of Fisher Scoring iterations: 5
```

Or see `lrm()` above

Model comparisons - likelihood-ratio tests

```
anova(glm0, glmFit, test="Chisq")
```

```
Analysis of Deviance Table

Model 1: postFac ~ 1
Model 2: postFac ~ DVpre + IV
  Resid. Df Resid. Dev Df Deviance  Pr(>Chi)
1        29     41.455
2        26     24.409  3   17.047 0.0006912 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
drop1(glmFit, test="Chi")
```

```
Single term deletions

Model:
postFac ~ DVpre + IV
       Df Deviance    AIC     LRT  Pr(>Chi)
<none>      24.409 32.409
DVpre   1   39.540 45.540 15.1319 0.0001003 ***
IV      2   26.566 30.566  2.1572 0.3400666
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Or see `lrm()` above

Model comparisons for testing IV

```
glmPre <- update(glmFit, . ~ . - IV) # no IV factor
anova(glmPre, glmFit, test="Chisq")
```

```
Analysis of Deviance Table

Model 1: postFac ~ DVpre
Model 2: postFac ~ DVpre + IV
  Resid. Df Resid. Dev Df Deviance Pr(>Chi)
1        28     26.566
2        26     24.409  2   2.1572   0.3401
```

Model comparisons for testing DVpre

```
anova(glm0, glmPre, test="Chisq")
```

```
Analysis of Deviance Table

Model 1: postFac ~ 1
Model 2: postFac ~ DVpre
  Resid. Df Resid. Dev Df Deviance Pr(>Chi)
1        29     41.455
2        28     26.566  1    14.89 0.000114 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Further resources

For penalized logistic regression, see packages `logistf` (http://cran.r-project.org/package=logistf) (using Firth's penalized likelihood) and `glmnet` (http://cran.r-project.org/package=glmnet). An example using `glmnet` for linear regression is in regressionRobPen.

Detach (automatically) loaded packages (if possible)

```
try(detach(package:rms))
try(detach(package:Hmisc))
try(detach(package:grid))
try(detach(package:lattice))
try(detach(package:survival))
try(detach(package:splines))
try(detach(package:Formula))
```

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R markdown (https://github.com/dwoll/RExRepos/raw/master/Rmd/regressionLogistic.Rmd) - markdown (https://github.com/dwoll/RExRepos/raw/master/md/regressionLogistic.md) - R code (https://github.com/dwoll/RExRepos/raw/master/R/regressionLogistic.R) - all posts (https://github.com/dwoll/RExRepos/)

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