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Analysis of covariance (ANCOVA)

- TODO
- Install required packages
- Test the effects of group membership and of covariate
 - Visually assess the data
 - Type I sum of squares
 - Type II/III sum of squares
 - Test individual regression coefficients
 - Visualize ANCOVA coefficients
- Effect size estimate
 - $\hat{\omega}^2$ for the group effect
- Planned comparisons between groups
 - Adjusted group means
 - Planned comparisons
- Detach (automatically) loaded packages (if possible)
- Get the article source from GitHub

TODO

- link to anovaSStypes

Install required packages

car (<http://cran.r-project.org/package=car>), effects (<http://cran.r-project.org/package=effects>),
multcomp (<http://cran.r-project.org/package=multcomp>)

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

Test the effects of group membership and of covariate

Visually assess the data

```

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)

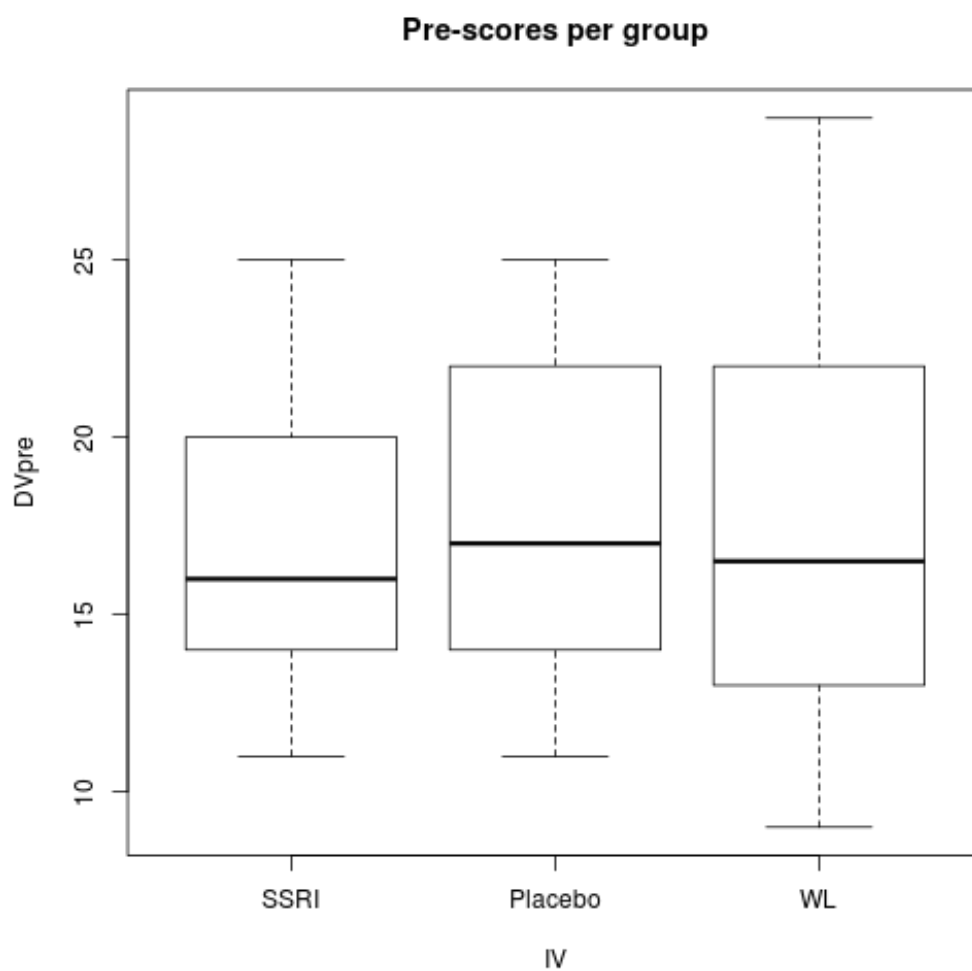
```

```

P <- 3
Nj <- rep(length(SSRIpre), times=P)
dfAnc <- data.frame(IV=factor(rep(1:P, Nj), labels=c("SSRI", "Placebo", "WL")),
  DVpre=c(SSRIpre, PlacPre, WLpre),
  DVpost=c(SSRIpost, PlacPost, WLpost))

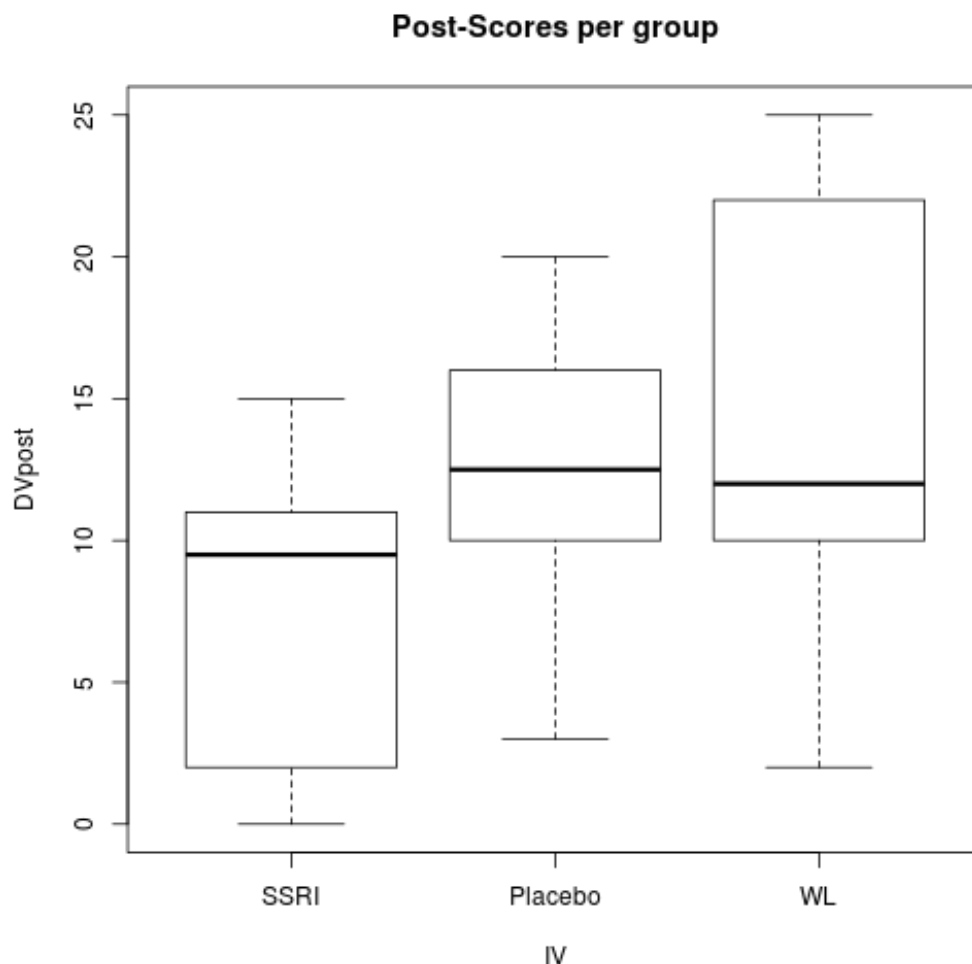
```

```
plot(DVpre ~ IV, data=dfAnc, main="Pre-scores per group")
```



plot of chunk rerAncova01

```
plot(DVpost ~ IV, data=dfAnc, main="Post-Scores per group")
```



plot of chunk rerAncova01

Type I sum of squares

```
fitFull <- lm(DVpost ~ IV + DVpre, data=dfAnc)
fitGrp  <- lm(DVpost ~ IV,          data=dfAnc)
fitRegr <- lm(DVpost ~ DVpre, data=dfAnc)
```

```
anova(fitFull)
```

Analysis of Variance Table

Response: DVpost

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
IV	2	240.47	120.23	4.1332	0.027629 *
DVpre	1	313.37	313.37	10.7723	0.002937 **
Residuals	26	756.33	29.09		

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

Type II/III sum of squares

Since no interaction is present in the model, SS type II and III are equivalent here.

Using Anova() from package car

```
library(car) # for Anova()
fitFiii <- lm(DVpost ~ IV + DVpre,
              contrasts=list(IV=contr.sum), data=dfAnc)
Anova(fitFiii, type="III")
```

Anova Table (Type III tests)

Response: DVpost

	Sum Sq	Df	F value	Pr(>F)
(Intercept)	0.00	1	0.0001	0.991035
IV	217.15	2	3.7324	0.037584 *
DVpre	313.37	1	10.7723	0.002937 **
Residuals	756.33	26		

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

Using model comparisons for SS type II

```
anova(fitRegr, fitFull)
```

Analysis of Variance Table

Model 1: DVpost ~ DVpre

Model 2: DVpost ~ IV + DVpre

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	28	973.48				
2	26	756.33	2	217.15	3.7324	0.03758 *

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

```
anova(fitGrp, fitFull)
```

Analysis of Variance Table

Model 1: DVpost ~ IV

Model 2: DVpost ~ IV + DVpre

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	27	1069.70				
2	26	756.33	1	313.37	10.772	0.002937 **

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

Test individual regression coefficients

```
(sumRes <- summary(fitFull))
```

Call:

```
lm(formula = DVpost ~ IV + DVpre, data = dfAnc)
```

Residuals:

Min	1Q	Median	3Q	Max
-10.6842	-3.9615	0.6448	3.8773	9.9675

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	-3.6704	3.7525	-0.978	0.33703
IVPlacebo	4.4483	2.4160	1.841	0.07703 .
IVWL	6.4419	2.4133	2.669	0.01292 *
DVpre	0.6453	0.1966	3.282	0.00294 **

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

Residual standard error: 5.393 on 26 degrees of freedom

Multiple R-squared: 0.4227, Adjusted R-squared: 0.3561

F-statistic: 6.346 on 3 and 26 DF, p-value: 0.002252

```
confint(fitFull)
```

	2.5 %	97.5 %
(Intercept)	-11.3836718	4.042941
IVPlacebo	-0.5178144	9.414373
IVWL	1.4812101	11.402537
DVpre	0.2411673	1.049464

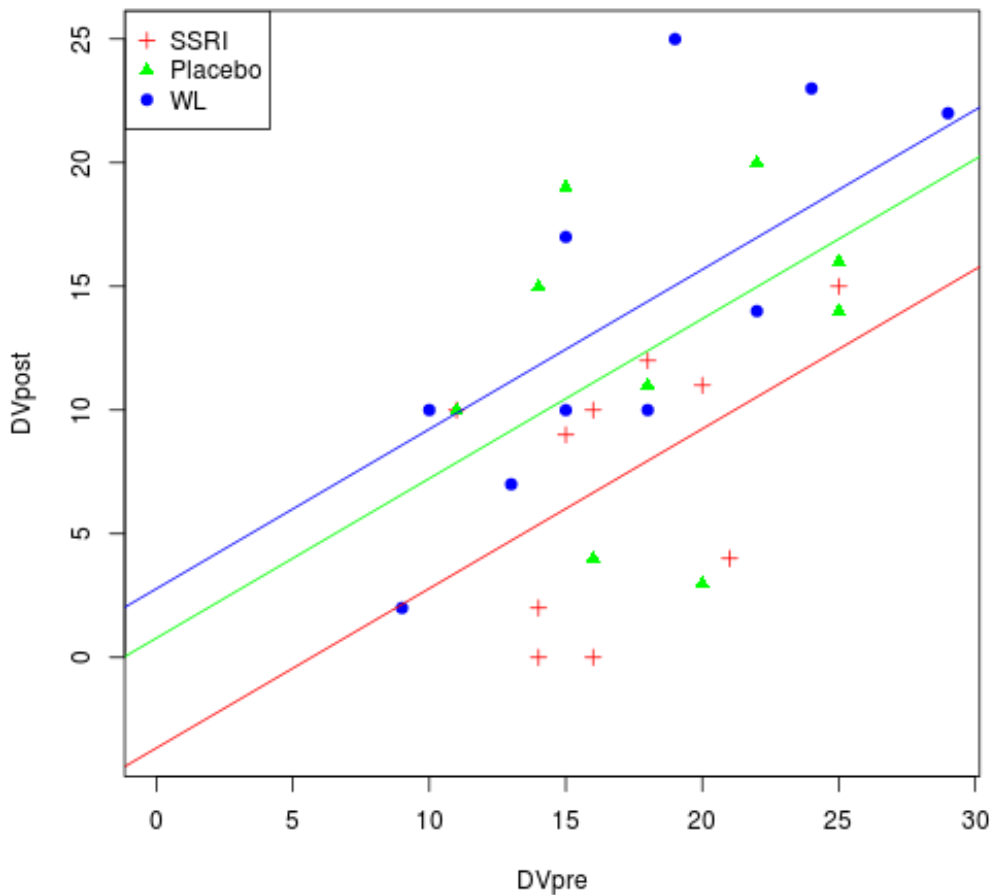
Visualize ANCOVA coefficients

```
coeffs <- coef(sumRes)
iCeptSSRI <- coeffs[1, 1]
iCeptPlac <- coeffs[2, 1] + iCeptSSRI
iCeptWL <- coeffs[3, 1] + iCeptSSRI
slopeAll <- coeffs[4, 1]
```

```
xLims <- c(0, max(dfAnc$DVpre))
yLims <- c(min(iCeptSSRI, iCeptPlac, iCeptWL), max(dfAnc$DVpost))

plot(DVpost ~ DVpre, data=dfAnc, xlim=xLims, ylim=yLims,
     pch=rep(c(3, 17, 19), Nj), col=rep(c("red", "green", "blue"), Nj),
     main="Data and group-wise regression lines")
legend(x="topleft", legend=levels(dfAnc$IV), pch=c(3, 17, 19),
      col=c("red", "green", "blue"))
abline(iCeptSSRI, slopeAll, col="red")
abline(iCeptPlac, slopeAll, col="green")
abline(iCeptWL, slopeAll, col="blue")
```

Data and group-wise regression lines



plot of chunk rerAncova02

Effect size estimate

$\hat{\omega}^2$ for the group effect

Using SS type II

```
anRes <- anova(fitRegr, fitFull)
dfGrp <- anRes[2, "Df"]
dfE <- anRes[2, "Res.Df"]
MSgrp <- anRes[2, "Sum of Sq"] / dfGrp
MSE <- anRes[2, "RSS"] / dfE
SST <- sum(anova(fitFull)[ , "Sum Sq"])

(omegaSqHat <- dfGrp*(MSgrp - MSE) / (SST + MSE))
```

```
[1] 0.1187001
```

Planned comparisons between groups

Adjusted group means

```
aovAncova <- aov(DVpost ~ IV + DVpre, data=dfAnc)
library(effects) # for effect()
YMjAdj <- effect("IV", aovAncova)
summary(YMjAdj)
```

```
IV effect
IV
      SSRI   Placebo      WL
7.536616 11.984895 13.978489

Lower 95 Percent Confidence Limits
IV
      SSRI   Placebo      WL
4.027629  8.476452 10.472608

Upper 95 Percent Confidence Limits
IV
      SSRI   Placebo      WL
11.04560 15.49334 17.48437
```

Planned comparisons

```
cMat <- rbind("SSRI-Placebo" = c(-1, 1, 0),
              "SSRI-WL"      = c(-1, 0, 1),
              "SSRI-0.5(P+WL)"= c(-2, 1, 1))
```

```
library(multcomp) # for glht()
aovAncova <- aov(DVpost ~ IV + DVpre, data=dfAnc)
summary(glht(aovAncova, linfct=mcp(IV=cMat), alternative="greater"),
        test=adjusted("none"))
```

Simultaneous Tests for General Linear Hypotheses

Multiple Comparisons of Means: User-defined Contrasts

Fit: aov(formula = DVpost ~ IV + DVpre, data = dfAnc)

Linear Hypotheses:

	Estimate	Std. Error	t value	Pr(>t)
SSRI-Placebo <= 0	4.448	2.416	1.841	0.03852 *
SSRI-WL <= 0	6.442	2.413	2.669	0.00646 **
SSRI-0.5(P+WL) <= 0	10.890	4.183	2.603	0.00753 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
(Adjusted p values reported -- none method)

Detach (automatically) loaded packages (if possible)


```
try(detach(package:effects))
try(detach(package:colorspace))
try(detach(package:lattice))
try(detach(package:grid))
try(detach(package:car))
try(detach(package:multcomp))
try(detach(package:survival))
try(detach(package:mvtnorm))
try(detach(package:splines))
try(detach(package:TH.data))
```

Get the article source from GitHub

R markdown (<https://github.com/dwoll/RExRepos/raw/master/Rmd/ancova.Rmd>) - markdown

(<https://github.com/dwoll/RExRepos/raw/master/md/ancova.md>) - R code

(<https://github.com/dwoll/RExRepos/raw/master/R/ancova.R>) - all posts

(<https://github.com/dwoll/RExRepos/>)

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