Untitled

Andrew Liu

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3a

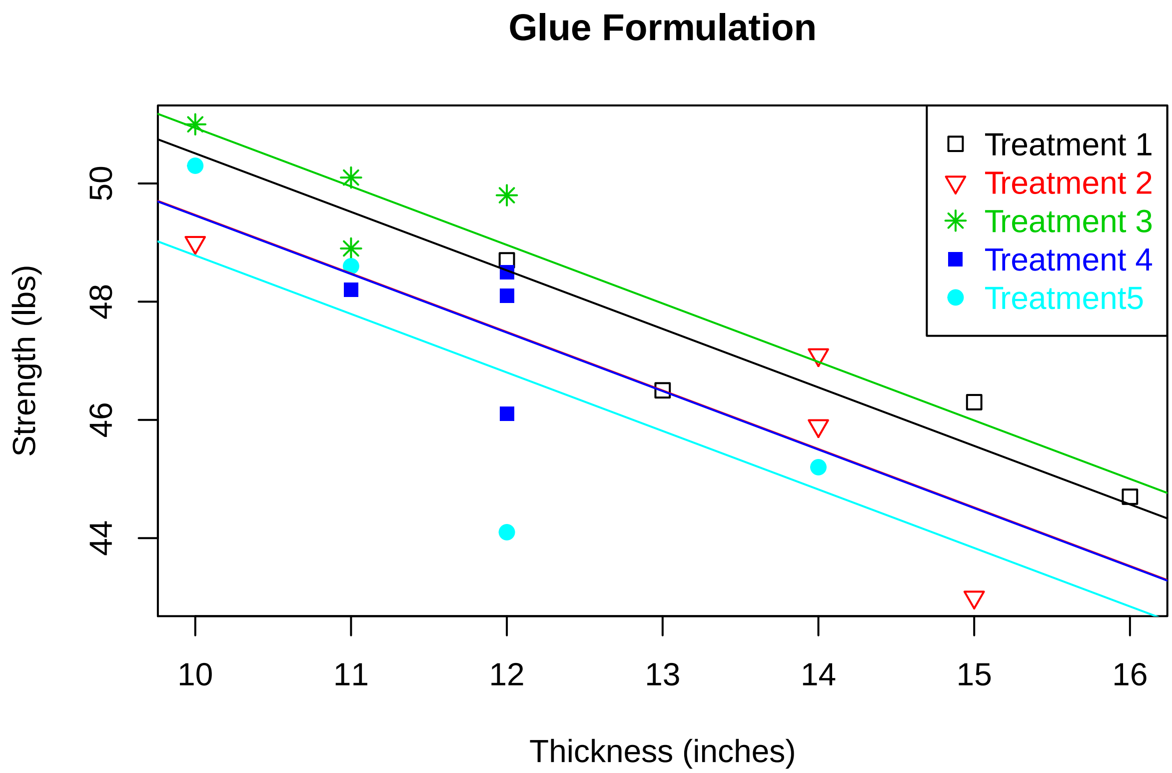
```r
y <- c(46.5,48.7,46.3,44.7,
       45.9,49,47.1,43,
       49.8,50.1,48.9,51,
       46.1,48.5,48.2,48.1,
       44.1,45.2,50.3,48.6)
x <- c(13,12,15,16,
       14,10,14,15,
       12,11,11,10,
       12,12,11,12,
       12,14,10,11)
form=as.factor(rep(1:4,5))
treat=as.factor(sort(rep(1:5,4)))
df1 = data.frame(treat,form,x,y)
```

```r
lm.full <- lm(y~x+treat,data=df1)
beta.hat <-  coef(lm.full)[2]

plot(df1$x,df1$y,col=sort(rep(1:5,4)),
    pch=sort(rep(c(0,6,8,15,19),4)),xlab="Thickness (inches)",
    ylab="Strength (lbs)",main="Glue Formulation")
legend("topright",legend=c("Treatment 1","Treatment 2","Treatment 3","Treatment 4", "Treatment5"),
    pch=c(0,6,8,15,19),col=1:5,text.col=1:5)

y.i.bar <- as.numeric(by(df1[,4],df1[,1],mean))
x.i.bar <- as.numeric(by(df1[,3],df1[,1],mean))


abline(y.i.bar[1]+beta.hat*(-x.i.bar[1]),beta.hat,col=1)
abline(y.i.bar[2]+beta.hat*(-x.i.bar[2]),beta.hat,col=2)
abline(y.i.bar[3]+beta.hat*(-x.i.bar[3]),beta.hat,col=3)
abline(y.i.bar[4]+beta.hat*(-x.i.bar[4]),beta.hat,col=4)
abline(y.i.bar[5]+beta.hat*(-x.i.bar[5]),beta.hat,col=5)
```



Upon visual inspection, it does appear that equal slopes is an appropriate assumption.

3b

```r
library(car)
```

```
## Warning: package 'car' was built under R version 3.4.4
## Loading required package: carData
## Warning: package 'carData' was built under R version 3.4.4
```

```r
out.lm <- lm(y~treat*x,data=df1,contrasts=list(treat=contr.sum))
Anova(out.lm,type="III")
```

```
## Anova Table (Type III tests)
##
## Response: y
##             Sum Sq Df  F value    Pr(>F)
## (Intercept) 290.145  1 139.9157 3.344e-07 ***
## treat         1.059  4   0.1277    0.9689
## x             8.996  1   4.3380    0.0639 .
## treat:x       1.786  4   0.2154    0.9239
## Residuals    20.737 10
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

testing against $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5$ yields $F^* = .2154$ distributed $F_{4,10}$ for a p-value of .9239. So we conclude that the test is not significant, and claim the equal slopes assumption appropriate.

3c

```r
out.aov <- aov(y~x+treat,data=df1)
Anova(out.aov, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: y
##             Sum Sq Df  F value    Pr(>F)
## (Intercept) 645.02  1 400.9220 1.059e-11 ***
## x            35.50  1  22.0681 0.0003427 ***
## treat        12.24  4   1.9022 0.1660140
## Residuals    22.52 14
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

If we test the equality of the adjusted treatment means we have $F^* = 1.9022$ which is distributed $F_{4,14} $ with a pvalue of .166, which is not significant. We then conclude that the adjusted treatment means are not significantly different.

3d

```r
out.aov <- aov(y~x+treat,data=df1)
Anova(out.aov, type="III")
```

```
## Anova Table (Type III tests)
##
## Response: y
##             Sum Sq Df  F value    Pr(>F)
## (Intercept) 645.02  1 400.9220 1.059e-11 ***
## x            35.50  1  22.0681 0.0003427 ***
## treat        12.24  4   1.9022 0.1660140
## Residuals    22.52 14
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

If we test the significance of the reduction in error variance due to the covariate we have $F^* = 22.0681$ which is distributed $F_{1,14} $ with a pvalue of .0003427, which is significant. We then conclude that the addition of the covariate has reduced error variability.

3e

```r
E.xx <- anova(lm(x~treat,data=df1))$"Sum Sq"[2]

MSE <- anova(lm.full)$"Mean Sq"[3]
x.bar <- mean(df1$x)
```

```r
y.i.adj <- y.i.bar-beta.hat*(x.i.bar-x.bar)

s.y.i <- sqrt(MSE*(1/4+(x.i.bar-x.bar)^2/E.xx))

#s.y.12 <- sqrt(MSE*(1/4+1/4+(x.i.bar[1]-x.i.bar[2])^2/E.xx))
#s.y.13 <- sqrt(MSE*(1/4+1/4+(x.i.bar[1]-x.i.bar[3])^2/E.xx))
#s.y.14 <- sqrt(MSE*(1/4+1/4+(x.i.bar[1]-x.i.bar[4])^2/E.xx))
#s.y.15 <- sqrt(MSE*(1/4+1/4+(x.i.bar[1]-x.i.bar[5])^2/E.xx))

#s.y.23 <- sqrt(MSE*(1/4+1/4+(x.i.bar[2]-x.i.bar[3])^2/E.xx))
#s.y.24 <- sqrt(MSE*(1/4+1/4+(x.i.bar[2]-x.i.bar[4])^2/E.xx))
#s.y.25 <- sqrt(MSE*(1/4+1/4+(x.i.bar[2]-x.i.bar[5])^2/E.xx))

#s.y.34 <- sqrt(MSE*(1/4+1/4+(x.i.bar[3]-x.i.bar[4])^2/E.xx))
#s.y.35 <- sqrt(MSE*(1/4+1/4+(x.i.bar[3]-x.i.bar[5])^2/E.xx))

#s.y.45 <- sqrt(MSE*(1/4+1/4+(x.i.bar[4]-x.i.bar[5])^2/E.xx))

lower.bound=y.i.adj-pt(.975,df=3)*s.y.i
upper.bound = y.i.adj+pt(.975,df=3)*s.y.i

library(xtable)
```

```
## Warning: package 'xtable' was built under R version 3.4.3
```

```r
tab.1<- data.frame(y.i.adj,s.y.i,lower.bound,upper.bound)
xtable(tab.1)
```

% latex table generated in R 3.4.0 by xtable 1.8-2 package % Thu Nov 29 01:57:09 2018

	y.i.adj	s.y.i	lower.bound	upper.bound
1	48.18	0.72	47.60	48.76
2	47.14	0.66	46.61	47.67
3	48.61	0.70	48.06	49.17
4	47.13	0.65	46.61	47.65
5	46.46	0.65	45.94	46.97