

1 Problem 18.4

Refer to Problem 16.7

Productivity improvement An economist ecompiled data on productivity improvements last year for a sample of firms producing electronic computing equipment. the firms were classified according to the level of their average expenditures for research and development in the past three years (low, moderate, high). The results of the study follow (productivity improvemtn is measured on a scale from 0 to 100).

	1	2	3	4	5	6	7	8	9	10	11	12
Low	7.6	8.2	6.8	5.8	6.9	6.6	6.3	7.7	6.0			
Moderate	6.7	8.1	9.4	8.6	7.8	7.7	8.9	7.9	8.3	8.7	7.1	8.4
High	8.5	9.7	10.1	7.8	9.6	9.5						

1.1 Residual dot plots

Prepare aligned residual dot plots by factor level. What departures from ANOVA model can be studied from these plots? What are your findings?

```
Y1 = c(7.6,8.2,6.8,5.8,6.9,6.6,6.3,7.7,6.0)
Y2 = c(6.7,8.1,9.4,8.6,7.8,7.7,8.9,7.9,8.3,8.7,7.1,8.4)
Y3 = c(8.5,9.7,10.1,7.8,9.6,9.5)
```

```
Y1bar = mean(Y1)
Y2bar = mean(Y2)
Y3bar = mean(Y3)
```

```
residuals = c(Y1-Y1bar,Y2-Y2bar,Y3-Y3bar)
factors = c(rep(1,9),rep(2,12),rep(3,6))
```

```
plot(residuals,factors)
```

1.2 Normal Probability Plot

Peprare a normal probability plot of the residuals. Also obtain the coefficients of correlation betwee the ordered residuals and their expected values under normality. Does the normality assumption appear to be reasonable here?

```
qqnorm(residuals)
```

```
# expected residuals
expected = qnorm(ppoints(residuals),0,1)

cor(expected,sort(residuals))
```

1.3 Location of Office

The economist wishes to investigate whether location of the firm's home office is related to productivity improvement. The home office locations are as follows (U: U.S.; E: Europe):

	1	2	3	4	5	6	7	8	9	10	11	12
1	U	E	E	E	E	U	U	U	U			
2	E	E	E	E	U	U	U	U	U	E	E	E
3	E	U	E	U	U	E						

Prepare aligned residual dot plots by factor level in which the location of the home office is identified. Does it appear that ANOVA model could be improved by adding location of home office as a second factor? Explain.

```
loc1 = c('U','E','E','E','E','U','U','U','U')
loc2 = c('E','E','E','E','U','U','U','U','U','E','E','E')
loc3 = c('E','U','E','U','U','E')

locations = c(loc1,loc2,loc3)

Uresiduals = residuals[locations=='U']
Ufactors = factors[locations=='U']

plot(Uresiduals,Ufactors,main="United States Location")

Eresiduals = residuals[locations=='E']
Efactors = factors[locations=='E']

plot(Eresiduals,Efactors,main="European Location")
```