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STAT 6305

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HW 2: 14.5a,b,c, 14.6a,b

14.5

Eng. **14.5** The production manager of a large investment casting firm is studying different methods to increase productivity in the workforce of the company. The process engineer and personnel in the human resource department develop three new incentive plans (B, C, D) for which they will design a study to compare the incentive plans with the current plan (plan A). Twenty workers are randomly assigned to each of the four plans. The response variable is the total number of units produced by each worker during one month on the incentive plans. The data are given here along with the output from Minitab.

	Incentive Plan			
Rep	**A**	**B**	**C**	**D**
1	422	521	437	582
2	431	545	422	639
3	784	600	473	735
4	711	406	478	800
5	641	563	397	853
6	709	361	944	748
7	344	387	394	622
8	599	700	890	514
9	511	348	488	714
10	381	944	521	627
11	349	545	387	548
12	387	337	633	644
13	394	427	627	736
14	621	771	444	528
15	328	752	1,467	595
16	636	810	828	572
17	388	406	644	627
18	901	537	1,154	546
19	394	816	430	701
20	350	369	508	664
Mean	514.1	557.2	628.3	649.8
St Dev	171.8	184.4	290.2	93.1

a. State the null and alternative hypothesis being tested by the F-statistics in the AOV table.

Hypotheses being tested:

$H_0: \mu_A = \mu_B = \mu_C = \mu_D$

$H_a:$ *At least one of the population mean units produced under a plan differs from the others*

b. Is there significant evidence ($\alpha = 0.05$) that the mean output associated with the four incentive plans is different?

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	236991.238	78997.079	2.02	0.1181
Error	76	2971586.650	39099.824		
Corrected Total	79	3208577.888			

No, there is not significant evidence that at least one is different from the others since the p-value $= 0.118 > 0.05$.

c. Use Fisher's LSD procedure to identify the pairs of incentive plans which have different mean output.

Alpha	0.05
Error Degrees of Freedom	76
Error Mean Square	39099.82
Critical Value of t	1.99167
Least Significant Difference	124.54

Means with the same letter are not significantly different.

t Grouping		Mean	N	method
	A	649.75	20	D
	A			
B	A	628.30	20	C
B	A			
B	A	557.25	20	B
B				
B		514.05	20	A

Fisher's LSD procedure suggests that there is a significant difference between treatment A and treatment D, but, as seen in part (b), we would not continue to this step because there is not significant evidence that any of the treatment means differ from the others.

14.6

14.6 In order for the conclusions reached in Exercise 14.5 to be valid, the conditions of normality, equal variance, and independence must be satisfied. Use the residuals from the fitted model to assess the three conditions. Refer to the discussion in Section 8.4, and the following output from Minitab.

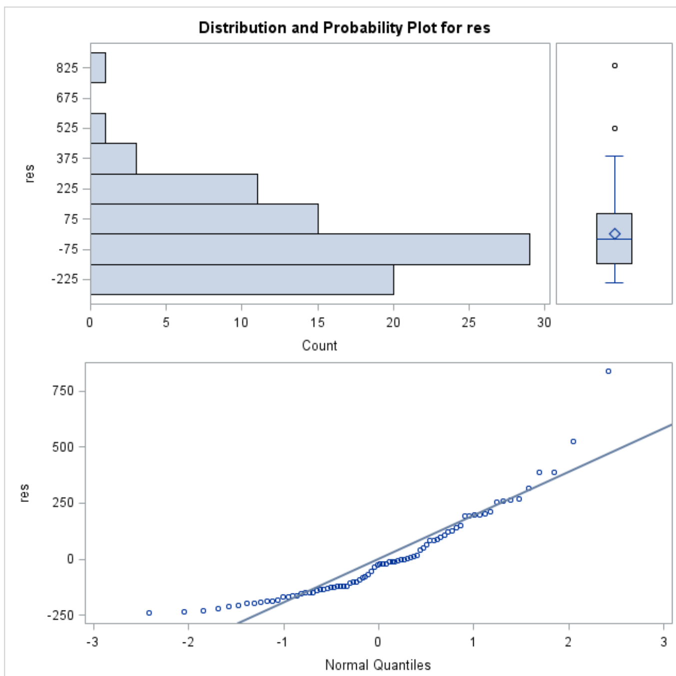
a. Was there significant evidence of a violation of the normality condition?

b. Was there significant evidence that the variance in reasoning scores was different for the three methods and the control?

c. What is the justification for concluding that the 100 reasoning scores are independent?

d. If the condition of normality and/or equal variance is violated, what are some alternative methods of analysis?

a. Was there significant evidence of a violation of the normality condition?



Shapiro-Wilk W: 0.883261 **Pr < W:** <0.0001

We see from the normal QQ-plot that the residual values deviate significantly from the regression line and the box plots do not look to match a normal curve. Further, the Shapiro-Wilk test gives a p-value less than 0.0001, signifying that we would reject the null hypothesis of normality. Thus, there is significant evidence that the normality condition is violated.

b. Was there significant evidence that the variance in reasoning scores was different for the three methods and the control?

Levene's Test for Homogeneity of Y Variance
ANOVA of Squared Deviations from Group Means

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
method	3	5.551E10	1.85E10	2.69	0.0519
Error	76	5.22E11	6.8684E9		

The Levene test for homogeneity of variances between the four treatments shows a p-value of 0.0519, implying that we would fail to reject the null hypothesis of equal variances between the four treatments at the significance level of $\alpha = 0.05$. Thus, we would conclude that there is not significant evidence that the variances between the four treatments are unequal. While this does not technically violate the equal variances condition of the ANOVA test at the stated significance level, the p-value is very close to being significant enough to conclude unequal variances.

Note: The result above does not agree with the result for the Levene test in the book. When the Levene test is performed using R (shown at the end of this document), the p-value is 0.112, which agrees with the result in the book.

SAS code:

```
* data entries;
data ex14_5;
input A B C D;
cards;
422 521 437 582
431 545 422 639
784 600 473 735
711 406 478 800
641 563 397 853
709 361 944 748
344 387 394 622
599 700 890 514
511 348 488 714
381 944 521 627
349 545 387 548
387 337 633 644
394 427 627 736
```

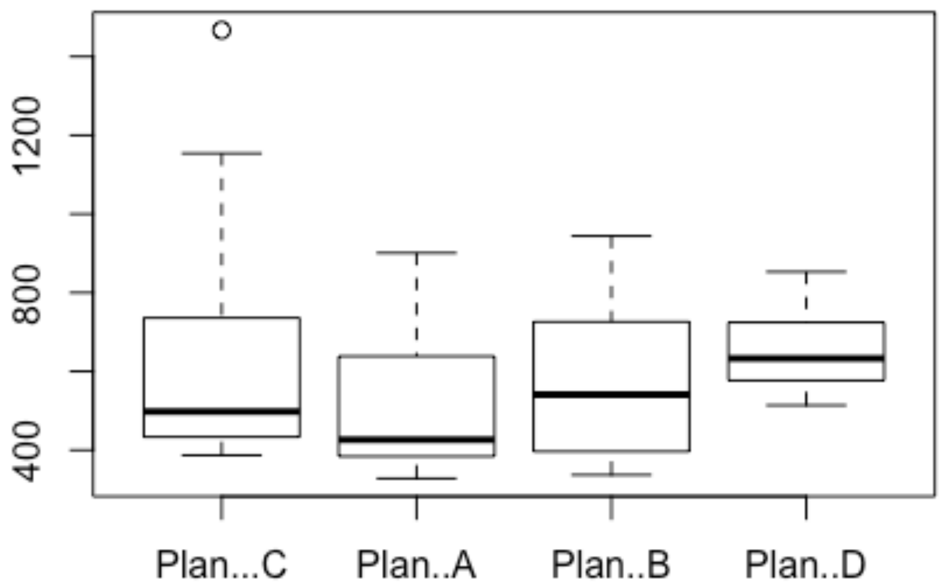
```
621 771 444 528
328 752 1467 595
636 810 828 572
388 406 644 627
901 537 1154 546
394 816 430 701
350 369 508 664
;
run;

* convert data set into a flat table;
data ex14_5flat; set ex14_5;
method = "A" ; Y=A; output;
method = "B" ; Y=B; output;
method = "C" ; Y=C; output;
method = "D" ; Y=D; output;
keep Y method;
run;

* run general linear model for ANOVA test;
* run LSD test for mean comparisons;
* create data set of residuals named resids;
proc glm data=ex14_5flat;
class method;
model Y=method;
means method / LSD;
means method / hovtest=levene;
output out=resids r=res;
run;
quit;

* test for normality: qq-plot, shapiro-wilks test;
proc univariate normal plot data=resids;
var res;
run;
```

R code:

R Markdown

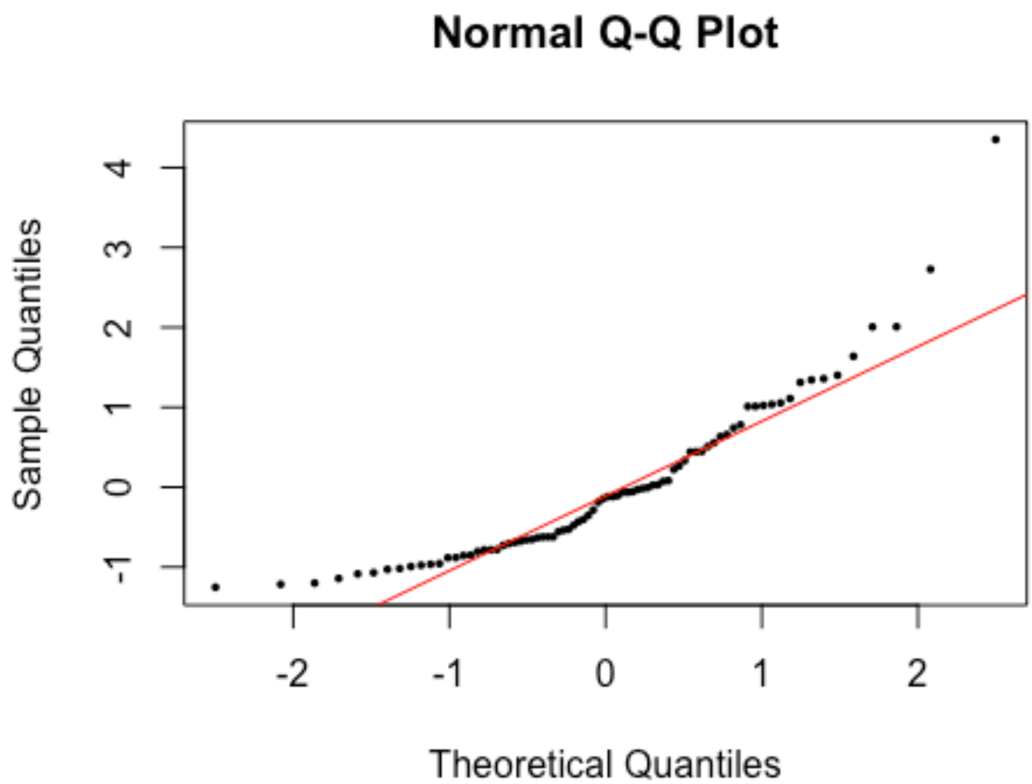
```
# 14.5
ex14.5 <- read.delim("~/Dropbox/Dropbox/STATS_6305/ex14-5.TXT", quote="'")

mydata<-as.data.frame(ex14.5[,2:5])
mdat <- stack(mydata)

# a.
```

```
# H0: mu(control) = mu = mu = mu
# Ha: One of the mus is different

boxplot(mdat$values~mdat$ind)
```




```
# b. No, as can be seen from output below, the p-value is 0.118
result<-aov(mdat$values~mdat$ind)
summary(result)

##             Df  Sum Sq Mean Sq F value Pr(>F)
## mdat$ind     3  236991   78997    2.02  0.118
## Residuals   76 2971587   39100

# c. None of the pairs have a significant difference at alpha = 0.05. However
, if we were to consider alpha =0.15, which is reasonable, than the A-D pair
would be significantly different.

TukeyHSD(result)

##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = mdat$values ~ mdat$ind)
##
```

```
## $`mdat$ind`
##                      diff        lwr       upr     p adj
## Plan..A-Plan...C -114.25 -278.50321  50.00321 0.2687517
## Plan..B-Plan...C  -71.05 -235.30321  93.20321 0.6684064
## Plan..D-Plan...C   21.45 -142.80321 185.70321 0.9860117
## Plan..B-Plan..A    43.20 -121.05321 207.45321 0.9002825
## Plan..D-Plan..A   135.70  -28.55321 299.95321 0.1409468
## Plan..D-Plan..B    92.50  -71.75321 256.75321 0.4549244

#14.6
#a. Yes, normality condition is violated:

r<-residuals(result)
rs<-rstandard(result)

# check the normality of residuals
qqnorm(rs, pch=16, cex=.5)
qqline(rs,col=2)
shapiro.test(rs)

##
##  Shapiro-Wilk normality test
##
## data:  rs
## W = 0.88326, p-value = 2.56e-06

#b.
library(car)
```




```r
leveneTest(mdat$values~mdat$ind)

## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value Pr(>F)
## group  3   2.062 0.1123
##       76

# Not enough significance to support Ha (not same variances) in this case
```