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Experimental Design & Analysis

2/16/18

**Homework 4 Code and Output**

1)

> batteryLife <- read.table("http://www.stat.uiowa.edu/~ernli/DOEdata/problem0330.txt", header=TRUE)

> batteryLifelm = lm(Life ~ factor(Brand), data=batteryLife)

> batteryLifelm

Call:

lm(formula = Life ~ factor(Brand), data = batteryLife)

Coefficients:

(Intercept) factor(Brand)2 factor(Brand)3

95.2 -15.8 5.2

> summary(aov(Life ~ factor(Brand), data = batteryLife))

Df Sum Sq Mean Sq F value Pr(>F)

factor(Brand) 2 1196.1 598.1 38.34 6.14e-06 \*\*\*

Residuals 12 187.2 15.6

> n=5

> a=3

> MSError=15.6

> ybars=c(95.2, (95.2-15.8), (95.2+5.2))

> alpha=0.05

> grandMean=mean(ybars)

> (difference=sum((ybars-grandMean)^2))

[1] 239.2267

> (ncp=(n\*difference)/MSError)

[1] 76.67521

> (Fcritical=qf(alpha,(a-1),(a\*n-a), lower.tail=FALSE))

[1] 3.885294

> (beta=pf(Fcritical,(a-1),(a\*n-a),ncp))

[1] 9.13325e-08

> (power=1-beta)

[1] 0.9999999

>power.anova.test(groups=a,n=n,between.var=var(ybars),within.var=MSError,sig.level=alpha,power=NULL)

Balanced one-way analysis of variance power calculation

groups = 3

n = 5

between.var = 119.6133

within.var = 15.6

sig.level = 0.05

power = 0.9999999

>power.anova.test(groups=a,n=NULL,between.var=var(ybars),within.var=MSError,sig.level=0.01,power=0.90)

Balanced one-way analysis of variance power calculation

groups = 3

n = 2.921976

between.var = 119.6133

within.var = 15.6

sig.level = 0.01

power = 0.9

2)

> soapTest <- read.table("http://www.stat.uiowa.edu/~ernli/DOEdata/problem0409.txt", header=TRUE)

> summary(lm(Growth ~ factor(Days) + factor(Solution), data=soapTest))

Call:

lm(formula = Growth ~ factor(Days) + factor(Solution), data = soapTest)

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 15.5833 2.0783 7.498 0.000291 \*\*\*

factor(Days)2 5.3333 2.3998 2.222 0.067976 .

factor(Days)3 0.6667 2.3998 0.278 0.790493

factor(Days)4 23.6667 2.3998 9.862 6.27e-05 \*\*\*

factor(Solution)2 2.2500 2.0783 1.083 0.320563

factor(Solution)3-15.0000 2.0783 -7.217 0.000359 \*\*\*

Residual standard error: 2.939 on 6 degrees of freedom

Multiple R-squared: 0.9722, Adjusted R-squared: 0.949

F-statistic: 41.91 on 5 and 6 DF, p-value: 0.0001371

> summary(aov(Growth ~ factor(Days) + factor(Solution), data=soapTest))

Df Sum Sq Mean Sq F value Pr(>F)

factor(Days) 3 1106.9 369.0 42.71 0.000192 \*\*\*

factor(Solution) 2 703.5 351.8 40.72 0.000323 \*\*\*

Residuals 6 51.8 8.6

> soapTestlm <- lm(Growth ~ factor(Days) + factor(Solution), data=soapTest)

> par(mfrow=c(2,2))

> plot(Growth ~ factor(Days) + factor(Solution), data=soapTest)

> qqnorm(residuals(soapTestlm), datax=TRUE)

> plot(fitted(soapTestlm), residuals(soapTestlm))



> nonadd=predict(soapTestlm)^2

> anova(update(soapTestlm,Growth ~ factor(Days) + factor(Solution) + nonadd))

Analysis of Variance Table

Response: Growth

Df Sum Sq Mean Sq F value Pr(>F)

factor(Days) 3 1106.92 368.97 55.3333 0.0002947 \*\*\*

factor(Solution) 2 703.50 351.75 52.7505 0.0004355 \*\*\*

nonadd 1 18.49 18.49 2.7732 0.1567331

Residuals 5 33.34 6.67

> interaction.plot(factor(soapTest$Days), factor(soapTest$Solution), soapTest$Growth)



> summary(aov(Growth ~ factor(Solution), data=soapTest))

Df Sum Sq Mean Sq F value Pr(>F)

factor(Solution) 2 703.5 351.8 2.732 0.118

Residuals 9 1158.7 128.7

> library(emmeans)

> emmeans(soapTestlm, pairwise ~ Solution)

$emmeans

Solution emmean SE df lower.CL upper.CL

1 23.00 1.469599 6 19.40402 26.59598

2 25.25 1.469599 6 21.65402 28.84598

3 8.00 1.469599 6 4.40402 11.59598

Results are averaged over the levels of: Days

Confidence level used: 0.95

$contrasts

contrast estimate SE df t.ratio p.value

1 - 2 -2.25 2.078327 6 -1.083 0.5578

1 - 3 15.00 2.078327 6 7.217 0.0009

2 - 3 17.25 2.078327 6 8.300 0.0004

Results are averaged over the levels of: Days

P value adjustment: tukey method for comparing a family of 3 estimates

> library(lme4)

> soapTestlmer=lmer(Growth ~ factor(Solution) + (1|Days), data=soapTest)

> summary(soapTestlmer)

Linear mixed model fit by REML ['lmerMod']

Formula: Growth ~ factor(Solution) + (1 | Days)

Data: soapTest

Fixed effects:

Estimate Std. Error t value

(Intercept) 23.000 5.673 4.054

factor(Solution)2 2.250 2.078 1.083

factor(Solution)3 -15.000 2.078 -7.217

> lsmeans(soapTestlmer, pairwise ~ Solution)

$lsmeans

Solution lsmean SE df lower.CL upper.CL

1 23.00 5.673403 3.28 5.796515 40.20349

2 25.25 5.673403 3.28 8.046515 42.45349

3 8.00 5.673403 3.28 -9.203485 25.20349

Degrees-of-freedom method: kenward-roger

Confidence level used: 0.95

$contrasts

contrast estimate SE df t.ratio p.value

1 - 2 -2.25 2.078327 6 -1.083 0.5578

1 - 3 15.00 2.078327 6 7.217 0.0009

2 - 3 17.25 2.078327 6 8.300 0.0004

> ybars = c(-3, 3, 0)

> a=3

> MSE=8.64

> alpha=.05

> power.anova.test(groups=a, n=NULL, between.var=var(ybars), within.var=MSE, sig.level=alpha, power=0.90)

Balanced one-way analysis of variance power calculation

groups = 3

n = 7.182777

between.var = 9

within.var = 8.64

sig.level = 0.05

power = 0.9

> summary(aov(Growth ~ factor(Days) + factor(Solution), data=soapTestCopy))

Df Sum Sq Mean Sq F value Pr(>F)

factor(Days) 3 960.8 320.3 124.9 4.03e-05 \*\*\*

factor(Solution) 2 682.3 341.2 133.1 4.62e-05 \*\*\*

Residuals 5 12.8 2.6

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

1 observation deleted due to missingness

3)

> hardness <- read.table("http://www.stat.uiowa.edu/~ernli/DOEdata/problem0412.txt", header=TRUE)

> summary(aov(Hardness ~ factor(Coupon) + factor(Tip), data=hardness))

Df Sum Sq Mean Sq F value Pr(>F)

factor(Coupon) 3 0.825 0.27500 30.94 4.52e-05 \*\*\*

factor(Tip) 3 0.385 0.12833 14.44 0.000871 \*\*\*

Residuals 9 0.080 0.00889

> hardnesslm <- lm(Hardness ~ factor(Coupon) + factor(Tip), data=hardness)

> emmeans(hardnesslm, pairwise ~ Tip, adjust="none")

$emmeans

Tip emmean SE df lower.CL upper.CL

1 9.575 0.04714045 9 9.468361 9.681639

2 9.600 0.04714045 9 9.493361 9.706639

3 9.450 0.04714045 9 9.343361 9.556639

4 9.875 0.04714045 9 9.768361 9.981639

Results are averaged over the levels of: Coupon

Confidence level used: 0.95

$contrasts

contrast estimate SE df t.ratio p.value

1 - 2 -0.025 0.06666667 9 -0.375 0.7163

1 - 3 0.125 0.06666667 9 1.875 0.0935

1 - 4 -0.300 0.06666667 9 -4.500 0.0015

2 - 3 0.150 0.06666667 9 2.250 0.0510

2 - 4 -0.275 0.06666667 9 -4.125 0.0026

3 - 4 -0.425 0.06666667 9 -6.375 0.0001

Results are averaged over the levels of: Coupon

> par(mfrow=c(2,2))

> plot(Hardness ~ factor(Coupon) + factor(Tip), data=hardness)

> qqnorm(residuals(hardnesslm), datax=TRUE)

> plot(fitted(hardnesslm), residuals(hardnesslm))



> nonadd=predict(hardnesslm)^2

> anova(update(hardnesslm,Hardness ~ factor(Coupon) + factor(Tip) + nonadd))

Analysis of Variance Table

Response: Hardness

Df Sum Sq Mean Sq F value Pr(>F)

factor(Coupon) 3 0.82500 0.27500 28.978 0.0001198 \*\*\*

factor(Tip) 3 0.38500 0.12833 13.523 0.0016877 \*\*

nonadd 1 0.00408 0.00408 0.430 0.5304111

Residuals 8 0.07592 0.00949

> interaction.plot(factor(hardness$Coupon), factor(hardness$Tip), hardness$Hardness)



> hardnesslmer=lmer(Hardness ~ factor(Tip) + (1|Coupon), data=hardness)

> summary(hardnesslmer)

Linear mixed model fit by REML ['lmerMod']

Formula: Hardness ~ factor(Tip) + (1 | Coupon)

Data: hardness

Fixed effects:

Estimate Std. Error t value

(Intercept) 9.57500 0.13731 69.73

factor(Tip)2 0.02500 0.06667 0.38

factor(Tip)3 -0.12500 0.06667 -1.88

factor(Tip)4 0.30000 0.06667 4.50

Correlation of Fixed Effects:

(Intr) fc(T)2 fc(T)3

factor(Tp)2 -0.243

factor(Tp)3 -0.243 0.500

factor(Tp)4 -0.243 0.500 0.500

> lsmeans(hardnesslmer, pairwise ~ Tip, adjust="none")

$lsmeans

Tip lsmean SE df lower.CL upper.CL

1 9.575 0.1373105 3.6 9.176402 9.973598

2 9.600 0.1373105 3.6 9.201402 9.998598

3 9.450 0.1373105 3.6 9.051402 9.848598

4 9.875 0.1373105 3.6 9.476402 10.273598

Degrees-of-freedom method: kenward-roger

Confidence level used: 0.95

$contrasts

contrast estimate SE df t.ratio p.value

1 - 2 -0.025 0.06666667 9 -0.375 0.7163

1 - 3 0.125 0.06666667 9 1.875 0.0935

1 - 4 -0.300 0.06666667 9 -4.500 0.0015

2 - 3 0.150 0.06666667 9 2.250 0.0510

2 - 4 -0.275 0.06666667 9 -4.125 0.0026

3 - 4 -0.425 0.06666667 9 -6.375 0.0001

> hardnessCopy <- hardness

> hardnessCopy["16", "Hardness"] <- NA

> summary(aov(Hardness ~ factor(Coupon) + factor(Tip), data=hardnessCopy))

Df Sum Sq Mean Sq F value Pr(>F)

factor(Coupon) 3 0.5557 0.1852 18.52 0.000585 \*\*\*

factor(Tip) 3 0.3017 0.1006 10.06 0.004333 \*\*

Residuals 8 0.0800 0.0100

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

1 observation deleted due to missingness