MATH 204 - MIDTERM EXAMINATION 2013

Q1: The Journal of Applied Psychology (June 2002) published a study of the recall of the content of television commercials. In a designed experiment, 324 adults were randomly assigned to one of three viewer groups: (i) Watch a TV program with a violent content code (V) rating, (ii) watch a show with a sex content code (S) rating, and, (iii) watch a neutral TV program. After viewing the program, each participant was scored on the number of brand names they could recall from the commercials.

A data analysis was carried out using `R`, and the results are presented below: `Y` denotes the recall score, `Code` the code of the commercial.

```
 1 > table(Code)
 2 Code
 3   N   V   S
 4 108 108 108
 5 > summary(aov(Y~Code))
 6              Df Sum Sq Mean Sq F value   Pr(>F)
 7 Code         --  123.3   ----   ----
 8 Residuals    --  967.4   ----
 9
10 > summary(lm(Y~Code))
11
12 Call: lm(formula = Y ~ Code)
13
14 Coefficients:
15             Estimate Std. Error t value Pr(>|t|)
16 (Intercept)   3.1667     0.1670  18.957  < 2e-16 ***
17 CodeV        -1.0833     0.2362  -4.586 6.49e-06 ***
18 CodeS        -1.4537     0.2362  -6.154 2.25e-09 ***
19 ---
20 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
21
22 Residual standard error: 1.736 on 321 degrees of freedom
23 F-statistic: 20.45 on 2 and 321 DF,  p-value: 4.364e-09
```

(a) Identify the experimental units, the factor, the factor levels, the response and the type of design used in this experiment.

5 Marks

(b) The table in lines 5-9 has five missing components indicated by dashes. On the answer sheet, write out the full table, including the omitted values.

5 Marks

(c) State precisely the null hypothesis being tested by the ANOVA procedure, and report the conclusion of the test. State the assumptions that the test relies upon.

5 Marks

(d) Explain the output presented in lines 10-20. Is recall score significantly higher or lower for coding `V` compared to coding `N` ?

5 Marks

(e) Using the `R` output, compute the sample means for data in each of the treatment groups, and also report the pooled estimate of the population variance.

5 Marks

S1: The Journal of Applied Psychology (June 2002) published a study of the recall of the content of television commercials. In a designed experiment, 324 adults were randomly assigned to one of three viewer groups: (i) Watch a TV program with a violent content code (V) rating, (ii) watch a show with a sex content code (S) rating, and, (iii) watch a neutral TV program. After viewing the program, each participant was scored on the number of brand names they could recall from the commercials.

A data analysis was carried out using `R`, and the results are presented below: `Y` denotes the recall score, `Code` the code of the commercial.

```
 1 > table(Code)
 2 Code
 3   N   V   S
 4 108 108 108
 5 > summary(aov(Y~Code))
 6              Df Sum Sq Mean Sq F value   Pr(>F)
 7 Code          --  123.3   ----   ----
 8 Residuals     --  967.4   ----
 9
10 > summary(lm(Y~Code))
11
12 Call: lm(formula = Y ~ Code)
13
14 Coefficients:
15             Estimate Std. Error t value Pr(>|t|)
16 (Intercept)   3.1667     0.1670  18.957  < 2e-16 ***
17 CodeV        -1.0833     0.2362  -4.586 6.49e-06 ***
18 CodeS        -1.4537     0.2362  -6.154 2.25e-09 ***
19 ---
20 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
21
22 Residual standard error: 1.736 on 321 degrees of freedom
23 F-statistic: 20.45 on 2 and 321 DF,  p-value: 4.364e-09
```

(a) Experimental units: adults; factor: viewing group; factor levels: code (N,V,S); response: recall score; type of design: CRD.

5 Marks

(b) We have

```
1 > summary(aov(Y~Code))
2              Df Sum Sq Mean Sq F value   Pr(>F)
3 Code          2  123.3   61.63   20.45 4.36e-09 ***
4 Residuals   321  967.4    3.01
```

5 Marks

(c) Null is 'no difference in response across Code values'; this is rejected as the F-value is more extreme than the 0.95 quantile of the $F(2, 321)$ density - see also the p-value in line 23. Assumptions needed are (i) independence, (ii) Normality within groups, (iii) equal variances across groups.

5 Marks

(d) This yields estimates of the intercept and contrast parameters in the analysis. It is evident from line 17 that the `V` code yields a significantly lower response than the `N` code (baseline group - see line 4 for labellings) as the contrast parameter is significantly negative.

5 Marks

(e) Three means are (lines 16-18) $3.1667, 3.1667 + (-1.0833) = 2.0833, 3.1667 + (-1.4537) = 1.7123$. Pooled estimate of variance is $MSE = 3.01 = (1.736)^2$.

5 Marks

Q1: The Journal of Experimental Psychology Applied (June 2000) studied of different methods of learning names. Three groups of students used different methods to learn the names of the other students in their group. Group 1 used the "simple name game," Group 2 used the "elaborate name game," and Group 3 used "pairwise introductions." The percentage of names recalled (after one year) by each student was recorded.

A data analysis was carried out using R, and the results are presented below: RECALL denotes the percentage score, GROUP the method group.

```
 1 > table(NameGame$GROUP)
 2  1  2  3
 3 50 42 47
 4 > summary(aov(RECALL~GROUP,data=NameGame))
 5              Df Sum Sq Mean Sq F value   Pr(>F)
 6 GROUP       ---  ----  3054.9    ----
 7 Residuals   ---  ----   397.4
 8
 9 > summary(lm(RECALL~GROUP,data=NameGame))
10
11 Coefficients:
12             Estimate Std. Error t value Pr(>|t|)
13 (Intercept)   30.640      2.819  10.868  < 2e-16 ***
14 GROUP2        -4.426      4.172  -1.061 0.290712
15 GROUP3       -15.512      4.050  -3.830 0.000195 ***
16 ---
17 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
18
19 Residual standard error: 19.93 on 136 degrees of freedom
20 F-statistic: 7.687 on 2 and 136 DF,  p-value: 0.0006872
```

(a) Identify the experimental units, the factor, the factor levels, the response and the type of design used in this experiment.

5 Marks

(b) The table in lines 4-7 has five missing components indicated by dashes. On the answer sheet, write out the full table, including the omitted values.

5 Marks

(c) State precisely the null hypothesis being tested by the ANOVA procedure, and report the conclusion of the test. State the assumptions that the test relies upon.

5 Marks

(d) Explain the output presented in lines 9-20. On the answer sheet, sketch a means plot demonstrating the variations in means across the groups.

5 Marks

(e) Using the R output, compute the sample means for data in each of the treatment groups, and also report the pooled estimate of the population variance.

5 Marks

S3: The Journal of Experimental PsychologyApplied (June 2000) studied of different methods of learning names. Three groups of students used different methods to learn the names of the other students in their group. Group 1 used the "simple name game," Group 2 used the "elaborate name game," and Group 3 used "pairwise introductions." The percentage of names recalled (after one year) by each student was recorded.

A data analysis was carried out using R, and the results are presented below: RECALL denotes the percentage score, GROUP the method group.

```
 1 > table(NameGame$GROUP)
 2  1  2  3
 3 50 42 47
 4 > summary(aov(RECALL~GROUP,data=NameGame))
 5              Df Sum Sq Mean Sq F value   Pr(>F)
 6 GROUP         ---  ----  3054.9    ----
 7 Residuals     ---  ----   397.4
 8
 9 > summary(lm(RECALL~GROUP,data=NameGame))
10
11 Coefficients:
12             Estimate Std. Error t value Pr(>|t|)
13 (Intercept)   30.640      2.819  10.868  < 2e-16 ***
14 GROUP2        -4.426      4.172  -1.061 0.290712
15 GROUP3       -15.512      4.050  -3.830 0.000195 ***
16 ---
17 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
18
19 Residual standard error: 19.93 on 136 degrees of freedom
20 F-statistic: 7.687 on 2 and 136 DF,  p-value: 0.0006872
```

(a) Experimental units: students; factor: Group; factor levels: Group 1,2,3; response: % names recalled; type of design: CRD.

5 Marks

(b) We have

```
1 > summary(aov(RECALL~GROUP,data=NameGame))
2              Df Sum Sq Mean Sq F value   Pr(>F)
3 GROUP         2   6110  3054.9   7.687 0.000687 ***
4 Residuals   136  54046   397.4
5 ---
6 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
```

5 Marks

(c) Null is 'no difference in response across Groups'; this is rejected as the F-value is more extreme than the 0.95 quantile of the $F(2, 136)$ density - see also the p-value in line 20. Assumptions needed are (i) independence, (ii) Normality within groups, (iii) equal variances across groups.

5 Marks

(d) This yields estimates of the intercept and contrast parameters in the analysis. This shows that Group 1 has the highest response (mean about 30), Group 2 the next highest (mean about 26, not significantly smaller), Group 3 the smallest (mean about 15, significantly smaller than the other two. The means plot should reflect this. Different C.I.s may be used; the simplest uses $s/\sqrt{n_i}$ for each of $i = 1, 2, 3$, where $s = 19.93$ (line 19).

5 Marks

(e) Means are $30.6400, 26.2143, 15.1277$. Pooled estimate of variance is $MSE = 397.4 = (19.93)^2$.

5 Marks

Q1: The Archives of Pediatrics and Adolescent Medicine (Dec. 2007) published a study of honey as a remedy for coughing. Coughing improvement scores for the patients in the over-the-counter cough medicine dosage (DM) group, honey dosage (H) group, and control (C) - corresponding to water - were recorded.

A data analysis was carried out using R, and the results are presented below: SCORE denotes the coughing improvement score, and GROUP the remedy groups.

```
 1 > table(Honey$GROUP)
 2  C DM  H
 3 37 33 35
 4 > summary(aov(SCORE~GROUP,data=Honey))
 5              Df Sum Sq Mean Sq F value  Pr(>F)
 6 GROUP       ---  318.5   ----   ----
 7 Residuals   ---  927.7   ----
 8
 9 > summary(lm(SCORE~GROUP,data=Honey))
10
11 Coefficients:
12             Estimate Std. Error t value Pr(>|t|)
13 (Intercept)   6.5135     0.4958  13.137  < 2e-16 ***
14 GROUPDM       1.8198     0.7221   2.520   0.0133 *
15 GROUPH        4.2008     0.7111   5.907 4.62e-08 ***
16 ---
17 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
18
19 Residual standard error: 3.016 on 102 degrees of freedom
20 F-statistic: 17.51 on 2 and 102 DF,  p-value: 2.902e-07
```

(a) Identify the experimental units, the factor, the factor levels, the response and the type of design used in this experiment.

5 Marks

(b) The table in lines 4-7 has five missing components indicated by dashes. On the answer sheet, write out the full table, including the omitted values.

5 Marks

(c) State precisely the null hypothesis being tested by the ANOVA procedure, and report the conclusion of the test. State the assumptions that the test relies upon.

5 Marks

(d) Explain the output presented in lines 9-20. On the answer sheet, sketch a means plot demonstrating the variations in means across the groups.

5 Marks

(e) Using the R output, compute the sample means for data in each of the treatment groups, and also report the pooled estimate of the population variance.

5 Marks

S2: The Archives of Pediatrics and Adolescent Medicine (Dec. 2007) published a study of honey as a remedy for coughing. Coughing improvement scores for the patients in the over-the-counter cough medicine dosage (DM) group, honey dosage (H) group, and control (C) - corresponding to water - were recorded.

A data analysis was carried out using R, and the results are presented below: SCORE denotes the coughing improvement score, and GROUP the remedy groups.

```
 1 > table(Honey$GROUP)
 2  C DM  H
 3 37 33 35
 4 > summary(aov(SCORE~GROUP,data=Honey))
 5              Df Sum Sq Mean Sq F value  Pr(>F)
 6 GROUP       ---  318.5   ----   ----
 7 Residuals   ---  927.7   ----
 8
 9 > summary(lm(SCORE~GROUP,data=Honey))
10
11 Coefficients:
12             Estimate Std. Error t value Pr(>|t|)
13 (Intercept)   6.5135     0.4958  13.137  < 2e-16 ***
14 GROUPDM       1.8198     0.7221   2.520   0.0133 *
15 GROUPH        4.2008     0.7111   5.907 4.62e-08 ***
16 ---
17 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
18
19 Residual standard error: 3.016 on 102 degrees of freedom
20 F-statistic: 17.51 on 2 and 102 DF,  p-value: 2.902e-07
```

(a) Experimental units: patients; factor: cough therapy; factor levels: cough medicine, honey, control; response: improvement score; type of design: CRD.

5 Marks

(b) We have

```
1 > summary(aov(SCORE~GROUP,data=Honey))
2              Df Sum Sq Mean Sq F value  Pr(>F)
3 GROUP         2  318.5   159.2   17.51 2.9e-07 ***
4 Residuals   102  927.7     9.1
5 ---
6 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
```

5 Marks

(c) Null is 'no difference in response across cough treatments'; this is rejected as the F-value is more extreme than the 0.95 quantile of the $F(2, 102)$ density - see also the p-value in line 20. Assumptions needed are (i) independence, (ii) Normality within groups, (iii) equal variances across groups.

5 Marks

(d) This yields estimates of the intercept and contrast parameters in the analysis. This shows that Control has the lowest response (mean about 6.5), DM has the next highest (mean about 8.3, significantly larger at $\alpha = 0.05$), Honey the smallest (mean about 10.7, significantly higher than the other two. The means plot should reflect this. Different C.I.s may be used; the simplest uses $s/\sqrt{n_i}$ for each of $i = 1, 2, 3$, where $s = 3.016$ (line 19).

5 Marks

(e) Means are $6.5135, 8.3333, 10.7143$. Pooled estimate of variance is $MSE = 9.1 = (3.016)^2$.

5 Marks

Q2: The absentee rates at a jeans production factory were measured (as the percentage of employees absent) over a nine week period, with rates recorded on the five working days Monday to Friday. Factory managers were interested to find out whether there was any significant difference between absentee rates across the days of the week.

An analysis of the data in `R` is recorded below, using a randomized block design, with week of study being a blocking factor. In the data, `AbsRate` represents absentee rate, `Week` denotes the week of the study, and `Day` denotes day of the week (`M,T,W,R,F` for days Monday through to Friday).

```
 1 > summary(aov(AbsRate~Day+Week,data=Jeans))
 2             Df Sum Sq Mean Sq F value    Pr(>F)
 3 Day         --   94.2   ----   ----       0.118
 4 Week        --  575.2   ----   ----    8.74e-05 ***
 5 Residuals   --  376.9   ----
 6
 7 > summary(lm(AbsRate~Day+Week,data=Jeans))
 8 Coefficients:
 9             Estimate Std. Error t value Pr(>|t|)
10 (Intercept)    4.791      1.845   2.597  0.01408 *
11 DayT          -4.244      1.618  -2.623  0.01323 *
12 DayW          -3.056      1.618  -1.889  0.06804 .
13 DayR          -3.489      1.618  -2.156  0.03867 *
14 DayF          -2.467      1.618  -1.525  0.13718
15 Week2          3.020      2.171   1.391  0.17374
16 Week3         -0.320      2.171  -0.147  0.88372
17 Week4          2.220      2.171   1.023  0.31411
18 Week5         12.280      2.171   5.657 2.93e-06 ***
19 Week6          4.360      2.171   2.009  0.05308 .
20 Week7          3.400      2.171   1.566  0.12710
21 Week8          6.480      2.171   2.985  0.00539 **
22 Week9          5.040      2.171   2.322  0.02676 *
23 ---
24 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
25
26 Residual standard error: 3.432 on 32 degrees of freedom
27 F-statistic: 4.736 on 12 and 32 DF,  p-value: 0.0002084
```

(a) Explain briefly why a randomized block design is considered appropriate here.

4 Marks

(b) The table in lines 1-5 has eight missing components indicated by dashes. On the answer sheet, write out the full table, including the omitted values.

8 Marks

(c) Report precisely the conclusion of the analysis implied by the ANOVA table.

4 Marks

(d) Explain how the results on line 5 (in the complete table) relate to the results on line 26.

4 Marks

(e) Using the results presented, report the estimated absentee rate for Friday in Week 4.

5 Marks

S4:

```
 1 > summary(aov(AbsRate~Day+Week,data=Jeans))
 2             Df Sum Sq Mean Sq F value    Pr(>F)
 3 Day         --   94.2   ----   ----       0.118
 4 Week        --  575.2   ----   ----    8.74e-05 ***
 5 Residuals   --  376.9   ----
 6
 7 > summary(lm(AbsRate~Day+Week,data=Jeans))
 8 Coefficients:
 9             Estimate Std. Error t value Pr(>|t|)
10 (Intercept)    4.791      1.845   2.597  0.01408 *
11 DayT          -4.244      1.618  -2.623  0.01323 *
12 DayW          -3.056      1.618  -1.889  0.06804 .
13 DayR          -3.489      1.618  -2.156  0.03867 *
14 DayF          -2.467      1.618  -1.525  0.13718
15 Week2          3.020      2.171   1.391  0.17374
16 Week3         -0.320      2.171  -0.147  0.88372
17 Week4          2.220      2.171   1.023  0.31411
18 Week5         12.280      2.171   5.657 2.93e-06 ***
19 Week6          4.360      2.171   2.009  0.05308 .
20 Week7          3.400      2.171   1.566  0.12710
21 Week8          6.480      2.171   2.985  0.00539 **
22 Week9          5.040      2.171   2.322  0.02676 *
23 ---
24 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
25
26 Residual standard error: 3.432 on 32 degrees of freedom
27 F-statistic: 4.736 on 12 and 32 DF,  p-value: 0.0002084
```

(a) Because it must be believed that the weeks are potentially systematically different in terms of their mean response; this turns out to be justified; see Week 5.

4 Marks

(b) We have

```
1 > summary(aov(AbsRate~Day+Week,data=Jeans))
2             Df Sum Sq Mean Sq F value   Pr(>F)
3 Day          4   94.2   23.55   1.999    0.118
4 Week         8  575.2   71.90   6.104 8.74e-05 ***
5 Residuals   32  376.9   11.78
6 ---
7 Signif. codes:  0  ***  0.001  **  0.01  *  0.05  .  0.1     1
```

8 Marks

(c) There is no significant difference in absentee rate across the days of the week, accounting for the differences due to blocks.

4 Marks

(d) Line 5 gives the MSE (11.78) which is the square of the residual standard error on line 26.

4 Marks

(e) This is computed as

$$4.791 + (-2.467) + 2.220 = 4.544$$

5 Marks

Q2: In an analysis of identification capabilities of eyewitnesses, ninety subjects were each shown a video of a simulated crime, and then shortly afterwards shown 180 "mugshot" photos, either in groups of 3, 6 or 12 photos. Each subject was then requested to select one or more of the mugshots from one set of sixty photos (either the first, middle or last set of sixty photos). The study was attempting to investigate whether either group size or set number, significantly influenced the number of selections made.

An analysis of the data in `R` is recorded below, using a factorial design. In the data, `NUMBER` represents the number of mugshots identified, `GROUP` denotes the number of mugshots shown at a time (3,6 or 12), and `SET` denotes whether questions were focused on the first, middle or last third of the mugshots presented.

```
 1 > summary(aov(NUMBER~GROUP+SET+GROUP:SET,data=Mug))
 2             Df Sum Sq Mean Sq F value   Pr(>F)
 3 GROUP       --  15.27   7.633   -----  0.000955 ***
 4 SET         --  62.60  31.300   -----  9.46e-11 ***
 5 GROUP:SET   --   7.13   1.783   1.772 0.142416
 6 Residuals   81  81.50   1.006
 7
 8 > summary(aov(NUMBER~GROUP+SET,data=Mug))
 9             Df Sum Sq Mean Sq F value   Pr(>F)
10 GROUP        2  15.27   7.633   -----  0.00117 **
11 SET          2  62.60  31.300   ----- 1.37e-10 ***
12 Residuals   --  88.63   1.043
13
14 > summary(lm(NUMBER~GROUP+SET,data=Mug))
15 Coefficients:
16             Estimate Std. Error t value Pr(>|t|)
17 (Intercept)   3.5667     0.2407  14.819  < 2e-16 ***
18 GROUP6       -0.9667     0.2637  -3.666 0.000428 ***
19 GROUP12      -0.7333     0.2637  -2.781 0.006666 **
20 SETMIDDLE    -1.6000     0.2637  -6.068 3.48e-08 ***
21 SETLAST      -1.9000     0.2637  -7.206 2.18e-10 ***
22
23 Residual standard error: 1.021 on 85 degrees of freedom
24 F-statistic: 18.67 on 4 and 85 DF,  p-value: 4.813e-11
```

(a) The tables in lines 1-12 have eight missing components indicated by dashes. On the answer sheet, write down the omitted values, clearly identifying the each value and its position.

8 Marks

(b) Report precisely the conclusion of the analysis implied by the ANOVA table in lines 1-6.

4 Marks

(c) Report precisely the conclusion of the analysis implied by the ANOVA table in lines 8-12.

4 Marks

(d) Explain the meaning of the output on line 24.

4 Marks

(e) On the basis of the results presented, predict the number of mugshots that would be selected when the GROUP size of 3 was used, and photos were selected from the MIDDLE set of sixty photos.

Which combination of GROUP and SET appears to lead to the **highest** number of selections being made ?

5 Marks

S5:

```
> summary(aov(NUMBER~GROUP+SET+GROUP:SET,data=Mug))
            Df Sum Sq Mean Sq F value   Pr(>F)
GROUP       --  15.27   7.633   -----  0.000955 ***
SET         --  62.60  31.300   -----  9.46e-11 ***
GROUP:SET   --   7.13   1.783   1.772 0.142416
Residuals   81  81.50   1.006

> summary(aov(NUMBER~GROUP+SET,data=Mug))
            Df Sum Sq Mean Sq F value   Pr(>F)
GROUP        2  15.27   7.633   -----  0.00117 **
SET          2  62.60  31.300   ----- 1.37e-10 ***
Residuals   --  88.63   1.043

> summary(lm(NUMBER~GROUP+SET,data=Mug))
Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   3.5667     0.2407  14.819  < 2e-16 ***
GROUP6       -0.9667     0.2637  -3.666 0.000428 ***
GROUP12      -0.7333     0.2637  -2.781 0.006666 **
SETMIDDLE    -1.6000     0.2637  -6.068 3.48e-08 ***
SETLAST      -1.9000     0.2637  -7.206 2.18e-10 ***

Residual standard error: 1.021 on 85 degrees of freedom
F-statistic: 18.67 on 4 and 85 DF,  p-value: 4.813e-11
```

(a) We have

```
> summary(aov(NUMBER~GROUP+SET+GROUP:SET,data=Mug))
            Df Sum Sq Mean Sq F value   Pr(>F)
GROUP        2  15.27   7.633   7.587 0.000955 ***
SET          2  62.60  31.300  31.108 9.46e-11 ***
GROUP:SET    4   7.13   1.783   1.772 0.142416
Residuals   81  81.50   1.006

> summary(aov(NUMBER~GROUP+SET,data=Mug))
            Df Sum Sq Mean Sq F value   Pr(>F)
GROUP        2  15.27   7.633    7.32  0.00117 **
SET          2  62.60  31.300   30.02 1.37e-10 ***
Residuals   85  88.63   1.043
```

8 Marks

(b) No evidence of interaction (p-value 0.142416) between the factors. 4 Marks

(c) Both factors significantly affect the response (both p-values are less than 0.05).

4 Marks

(d) That line reports the significance test with null hypothesis that specifies 'no effect of either factor' against the general alternative. The result is strongly significant.

4 Marks

(e) This would be

$$3.5667 + 0 + (-1.6000) = 1.9667$$

The highest number of selections is predicted when a group of 3 is used, and the first set is used (ie the baseline group); this is because all contrasts are negative.

5 Marks