NTHU STAT 5510 Midterm Examination April 27, 2023

Instructions: Attempt all questions. Short and specific answers are preferred. Given explanation when required, but keep it as short and simple as possible. Give only one answer to each question – if you give alternative answers, the worst answer will be graded.

Question A.

For each of the following experiments,

(a) identify its treatment factor(s) and block factor(s) (or covariate),
(b) determine the types (i.e., qualitative or quantitative) and numbers of levels of these factors,
(c) identify the experimental units,
(d) suggest an appropriate conceptual model,
(e) recognize the design plan(s) (e.g., one-way layout, two-way layout, multi-way layout, completely randomized design, paired comparison design, randomized block design, Latin square design, BIBD, analysis of covariance, ...) that is suitable for the experiment.

(1) (3 pts) An experiment was run to understand the effect of sulfamerazine on the hemoglobin content of trout blood. The trout were placed at random in 4 different troughs. The fish food added to the troughs contained, respectively, 0, 5, 10, and 15 grams of sulfamerazine per 100 pounds of fish. The hemoglobin measurements were made on 10 randomly selected fish from each trough after 35 days.

(2) (3 pts) An experiment was run to compare the light intensities of different brands of light bulbs. Three brands were selected. A further variable that was examined in the experiment was the effect of the percentage capacity of the bulb, which was controlled by the amount of current being passed through the bulb. Two levels of capacity were selected, 50% and 100%. The experiments used both 60 watt bulbs and 100 watt bulbs. Comparison of illumination between two different wattages was not of particular interest, since 100 watt bulbs should be brighter than 60 watt bulbs. The experiment need to be run at two separate times, so it was convenient to examine the 60 watt bulbs on one day and the 100 watt bulbs on another. At each day, 24 bulbs were used.

Question B.

An experiment performed at the National Wildlife Health Research Center examined the effect of a certain bacteria strain (mycoplasma) on the development of mallard ducks. The response variable was bill length in mm. There were three factors studies in the experiment. The temperature of the room can be warm or cold. The mycoplasma or a control can be injected. Either the egg or the newly hatched chick may be inoculated. Measurements were taken on 194 chicks, 3 weeks after birth. This experiment was conducted in two runs separated by several weeks. Several things could have changed in that time, including the mycoplasma culture, seasonal changes of chick growth and food or water conditions. The

scientist inoculated eggs in the first run, but decided to switch to inoculating young chicks in the later run.

(3) (1 pt) Was a balanced layout used? Explain.

Boxplots of the data and the main-effect plot are shown in Figure 1.

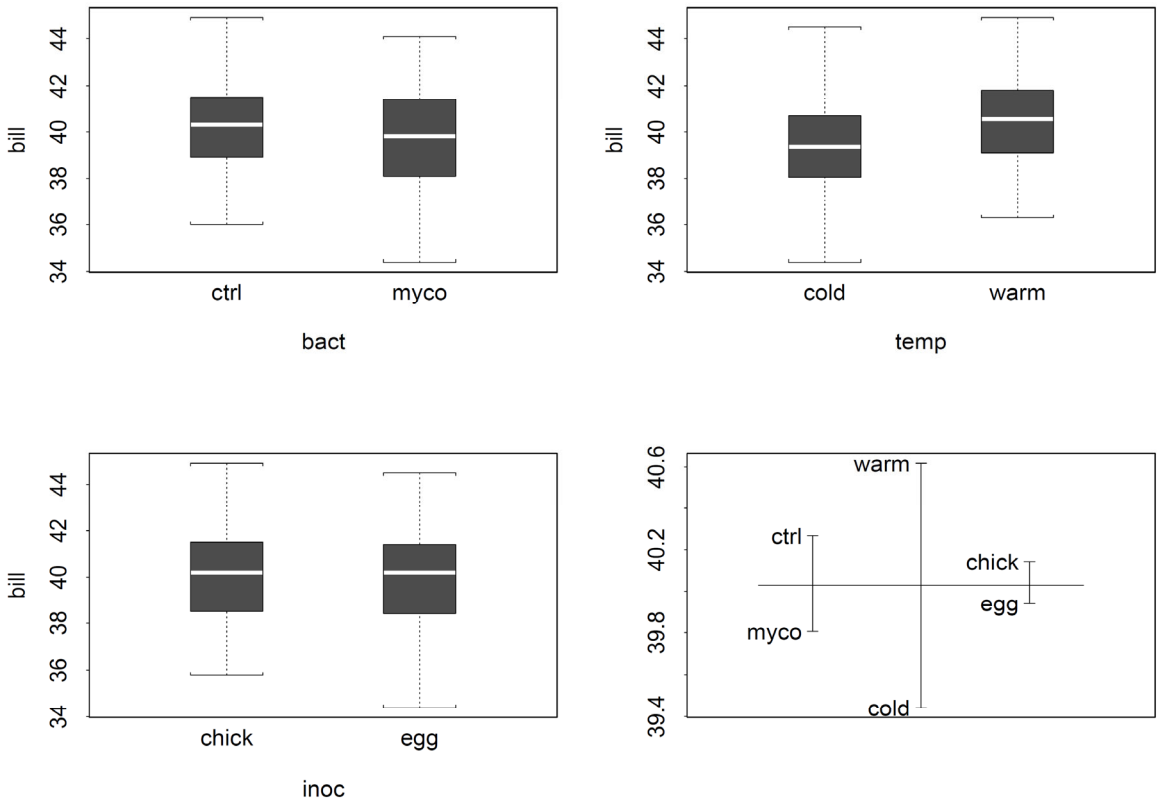

Figure 1. Boxplots and Main-effect plot

(4) (2 pts) Explain what features should one look for in the boxplots and say what conclusions should be made in this case.

(5) (1 pt) Is it possible to infer normality from these boxplots? Explain.

(6) (1 pt) Suppose histograms of these data for each level combinations showed that the data was not normal. What impact would this have on our analysis?

A full 3-way ANOVA model was fit and the following sequential ANOVA table was obtained:

Response: bill

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
bact	1	10.2212	10.22119	2.58707	0.1095
temp	1	65.8529	65.85286	16.66790	0.0001
inoc	1	8.3300	8.33001	2.10839	0.1482
bact:temp	1	6.3244	6.32436	1.60075	0.2074
bact:inoc	1	5.2185	5.21846	1.32083	0.2519

temp:inoc	1	6.6583	6.65829	1.68527	0.1958
bact:temp:inoc	1	0.0136	0.01364	0.00345	0.9532
Residuals	186	726.9620	3.95088		

(7) (1 pt) What is the estimated value of $\hat{\sigma}$ in the full model?

(8) (2 pts) Exam whether we can simultaneously remove all the interactions from the model.

[**Hint**. $F_{4,186}^{(0.05)} = 2.42$.]

(9) (2 pts) Describe which factor(s) affect bill length and indicate which levels tend to increase bill length. Explain how you get your answer.

(10) (2 pts) What can be said about the effect of inoculating the egg as opposed to the chick? Explain.

Question C.

An experimenter wished to compare the shelf life of loaves made from 3 different bread doughs, coded 1, 2, 3. An oven with three shelves was used, and each shelf was large enough to take 3 baking tins. A temperature difference was anticipated between the different shelves but not in different positions within a shelf. The oven was used once, giving a total of 3 blocks, coded I, II, III. The model matrix for the data under the treatment coding (i.e., 0-1 coding) is given below:

observations	(Intercept)	blockII	blockIII	dough2	dough3
1	1	0	0	0	0
2	1	0	0	1	0
3	1	0	0	0	1
4	1	1	0	0	0
5	1	1	0	1	0
6	1	1	0	0	1
7	1	0	1	0	0
8	1	0	1	1	0
9	1	0	1	0	1

(11) (1 pt) Examine whether the 2-dimsional space spanned by the columns `blockII` and `blockIII` is (geometrically) orthogonal to the 2-dimsional space spanned by the columns `dough2` and `dough3`.

(12) (1 pt) Examine whether the estimates of block effects and treatment (dough) effects are correlated by obtaining the correlation between the effect estimates corresponding the columns `blockII` and `dough2`.

Under the treatment coding given above, a sequential ANOVA is performed using the R command:

```
> anova(lm(y~dough+block))
```

The ANOVA output is:

```
Response: y
             Df     Sum Sq    Mean Sq    F value    Pr(>F)
dough        2      2620.23   ??         2.2921     0.2171
block        2      ??        23.59      ??         0.9600
Residuals    ??     2286.31   ??
```

(13) (2 pts) Under the treatment coding, the order of `dough` and `block` is reversed in a new R command (i.e., using the command `anova(lm(y~block+dough))`). Give the complete `Df` and `Sum Sq` values in the ANOVA output of the *new* command and explain how you obtain it.

Question D.

Five suppliers cut denim material for a jeans manufacturer. An algorithm is used to estimate how much material will be wasted given the dimensions of the material supplied. Typically, a supplier wastes more material than the target based on the algorithm although occasionally they waste less. The percentage of waste relative to target was collected weekly for the 5 suppliers. In all, 95 observations were recorded. The data are displayed in Figure 2.

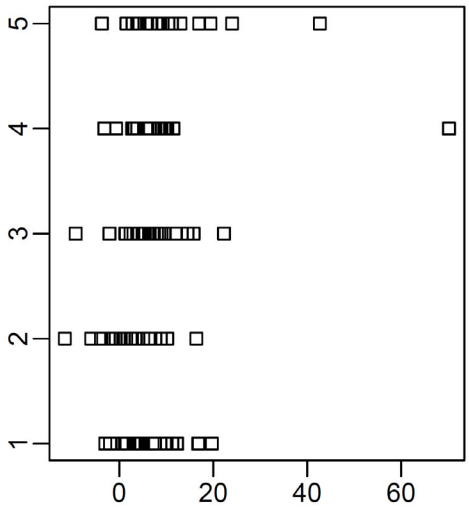

Figure 2: Plots of denim waste by supplier

(14) (1 pt) What action would you take as a result of seeing this first plot?

After taking the appropriate action (for this and the following questions), a regression model was fit to the data and the following summary obtained:

```
Coefficients:
             Estimate  Std. Error    t value    Pr(>|t|)
(Intercept)  6.405     1.316         4.87       4.9e-06
supplier2    -4.240    1.907         -2.22      0.029
```

```
supplier3    0.300     1.907        0.16      0.875
supplier4    -0.751    2.066        -0.36     0.717
supplier5    2.770     2.028        1.37      0.175

Residual standard error: 6.17 on 88 degrees of freedom
Multiple R-Squared: 0.123, Adjusted R-squared: 0.0831
F-statistic: 3.09 on 4 and 88 DF, p-value: 0.0199
```

(15) (1 pt) The number of observations per supplier were not all necessarily the same. For which suppliers were the same number of observations taken based on the information given above? Explain.

The 95% Tukey HSD confidence intervals were calculated:

	diff	lwr	upr
2-1	-4.23955	-9.54979	1.0707
3-1	0.30045	-5.00979	5.6107
4-1	-0.75121	-6.50641	5.0040
5-1	2.77045	-2.87680	8.4177
3-2	4.54000	-0.89521	9.9752
4-2	3.48833	-2.38237	9.3590
5-2	7.01000	1.24509	12.7749
4-3	-1.05167	-6.92237	4.8190
5-3	2.47000	-3.29491	8.2349
5-4	3.52167	-2.65554	9.6989

(16) (1 pt) Which pairs of suppliers had a statistically significant difference?

(17) (1 pt) Observations were taken over a period of 22 weeks. Some suppliers stopped take measurements before the end of the 22-week period so there are fewer than 110 observations. If we include a week factor in the model, should it be regarded as a treatment factor or a block factor? Explain.

(18) (1 pt) Suppose that we wish to test for supplier effects in the presence of possible week effects. Which two models (i.e., null and alternative models) should be compared to test whether any of the supplier effects are significant?

(19) (1 pt) If we calculate Tukey confidence intervals again under the full model adopted in problem (18), would we get the same `diff` as given above? Explain.

(20) (2 pts) Suppose that we treat the `week` as a quantitative variable taking integer values from 1 to 22 and fit the model `waste ~ week + supplier`. How many degrees of freedom would `week` have in this model? What is the name of the analysis for testing supplier effects under this model?