STAT 5200 Fall 2018 Midterm Exam

Do not open the exam until you are instructed to do so.

Directions: You have 70 minutes to complete the exam. You may use your calculator and a single page (both sides) of handwritten notes, but no laptops or wireless-capable devices are allowed. Be concise with all your responses (no more than 1-2 sentences are needed for each question). You may use 2 or 3 decimal places in all calculations. The point-worth of each question is given, and the total points sum to 100.

Student Name: _____

SAS Output: Partial SAS code, output, and graphics (all clearly identified by title or output number) from certain models are provided in a separate handout, and are necessary for some of the questions on the exam.

Statistical Significance: For all significance tests on this exam, use significance level $\alpha = 0.05$. Where multiple hypotheses are concerned, control the strong family-wise error rate at $\alpha = 0.05$.

Study: 96 elderly American male subjects with the same brand of hearing aid (and approximately the same degree of hearing loss) were recruited by the hearing aid manufacturer in a study of their product's performance under various conditions. There were 4 recordings of the same male speaker reading the same list of 50 words under various conditions (SAS variable '**`recording`**'), and 24 subjects were randomly assigned to each of the recordings. The recordings were arbitrarily numbered 1-4. While listening to their assigned recording, each subject repeated back each word as they heard it. An observer marked each word on the list as correctly or incorrectly identified by the subject, and the subject's score (SAS variable '**`score`**') was their total number of correctly identified words.

Question 1: (4 points) Identify the key feature of this study that makes it a good experiment.

Question 2: Refer to the code and output for SAS Output 1.

a) (10 points) Write out an appropriate model corresponding to this SAS code, using the means model parameterization. Define any symbols (parameters or letters) you use, and specify the range of any subscripts you use.

b) (10 points) Identify two assumptions made by this model (in Question 2a above), referring to a specific component of the model. For each assumption, comment briefly on what the evidence in SAS Output 1 suggests regarding the appropriateness of the assumption. (The code and output for SAS Output 2 may also be helpful.)

i) Assumption:

Piece of evidence:

What evidence suggests:

ii) Assumption:

Piece of evidence:

What evidence suggests:

Question 3: (6 points) Why must the assumptions you mention in Question 2b above be addressed before proceeding with statistical inference?

Question 4: Refer again to the code and output for SAS Output 1. Report the following:

a) (6 points) The numeric value of the test statistic for the null hypothesis 'mean score is the same for all four recordings.'

b) (3 points) The sampling distribution for this test statistic.

c) (1 point) The p-value for the null in part (a) above.

d) (5 points) The conclusion of this test of significance, in the context of this application.

e) (4 points) The percentage of variation in subject score explained by the differences among the four recordings.

Question 5: (12 points) Refer to the code and output for SAS Output 3. The LSMEANS statement (which does not depend on the MEANS statement) produces the following table of raw, unadjusted p-values. We are interested in all pairwise comparisons of recording means, and we want to control the strong family-wise error rate at $\alpha = 0.05$ while maintaining the highest statistical power. Based on this interest and using the appropriate table in SAS Output 3, circle which of these unadjusted p-values **would** be called statistically significant after appropriate adjustment. (Here, LSMEAN numbers 1-4 are the same as recording numbers 1-4.)

Least Squares Means for effect recording
Pr > |t| for H0: LSMean(i)=LSMean(j)
Dependent Variable: score

i/j	1	2	3	4
1		0.3632	0.0014	0.0022
2			0.0196	0.0282
3				0.8841
4				

Question 6: (12 points) Now you deserve some additional information about the four recordings. They are actually based on the combinations of the following two other factors: the accent used by the speaker in the recording (either American or British; SAS variable '**`Accent`**') and the type of background noise in the recording (either soft radio static or soft classical music; SAS variable '**`Background`**'), as summarized in this table:

`recording`	1	2	3	4
`Accent`	American	British	British	American
`Background`	Static	Music	Static	Music

Using parameters you defined in Question 2 above, define a contrast ψ, where H_0: $\psi = 0$ corresponds to a test of whether speaker accent has any effect on subject score.

Question 7: With the additional information about factors **`Accent`** and **`Background`** from Question 6 above, refer to the code and output for SAS Output 4, as well as the initial description of the study (on the first page of this exam).

a) (4 points) This is a _____ by _____ factorial design with _____ replicates at each factor level combination. (Fill in the blanks.)

b) (4 points) What is the experimental unit in this design?

c) (4 points) The measurement unit in this design is not the same as the experimental unit. What is the measurement unit in this design?

d) (7 points) The interaction term is significant here (P-value 0.0002). Without referring to the interaction plot, what does it mean to say there is an interaction here?

e) (7 points) An observer sees that the P-value for **`Accent`** (0.4554) is not significant, and says that you can conclude that speaker accent does not affect score. Referring to specific evidence in SAS Output 4, explain clearly why the observer's conclusion is wrong, and how speaker accent does affect score.

Question 8: (1 point) What topic(s) did you study most that did not appear on this exam?

SAS Code & Output for STAT 5200 Fall 2018 Midterm Exam

```
proc glm data=hearing plots=diagnostic;
     class recording;
     model score = recording;
     title1 'SAS Output 1';
run;
```

SAS Output 1

The GLM Procedure

Class Level Information		
Class	**Levels**	**Values**
recording	4	1 2 3 4

Dependent Variable: score

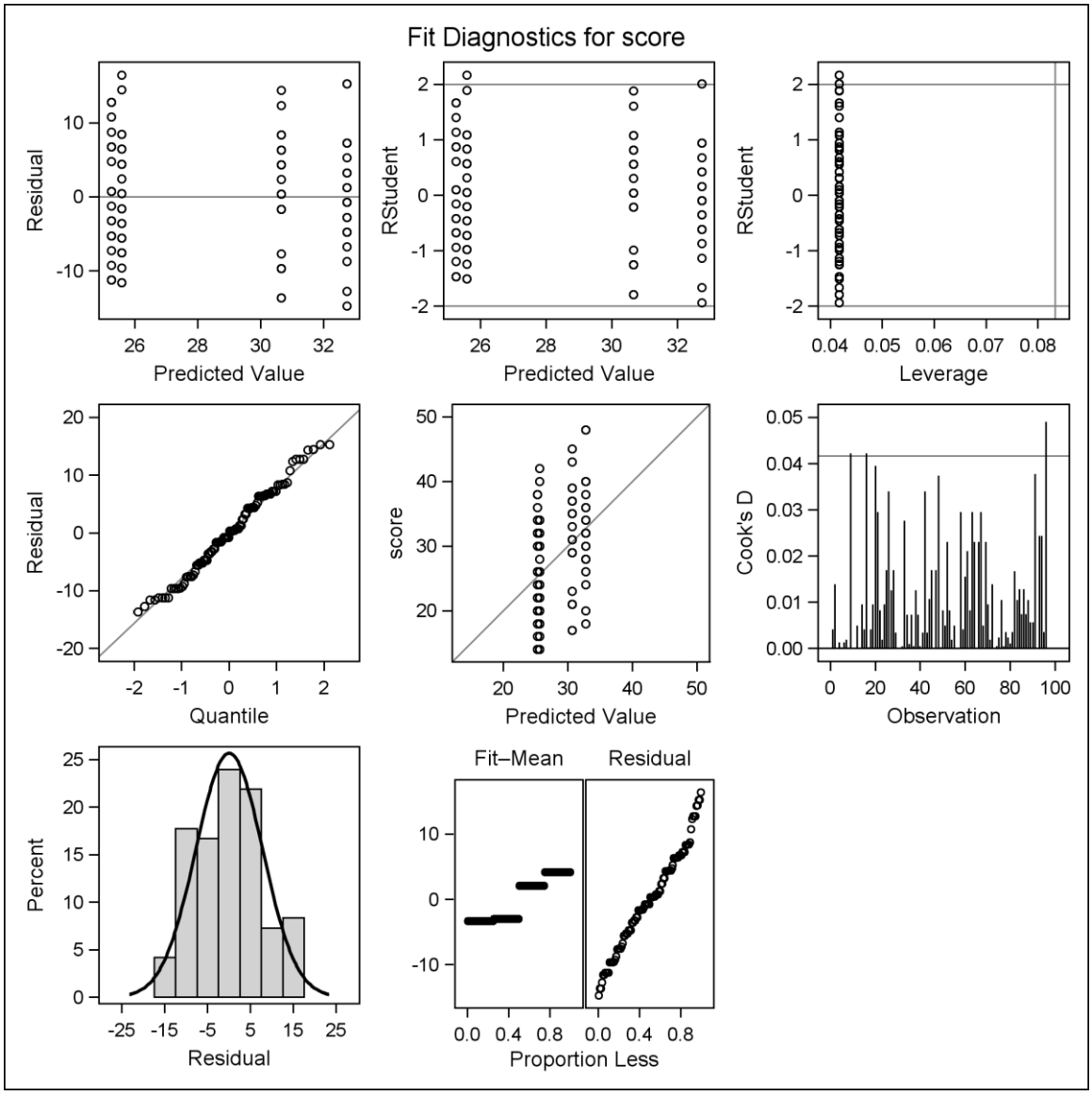
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1003.458333	334.486111	[redacted]	0.0019
Error	92	5738.166667	62.371377		
Corrected Total	95	6741.625000			

Source	DF	Type I SS	Mean Square	F Value	Pr > F
recording	3	1003.458333	334.486111	[redacted]	0.0019

Source	DF	Type III SS	Mean Square	F Value	Pr > F
recording	3	1003.458333	334.486111	[redacted]	0.0019

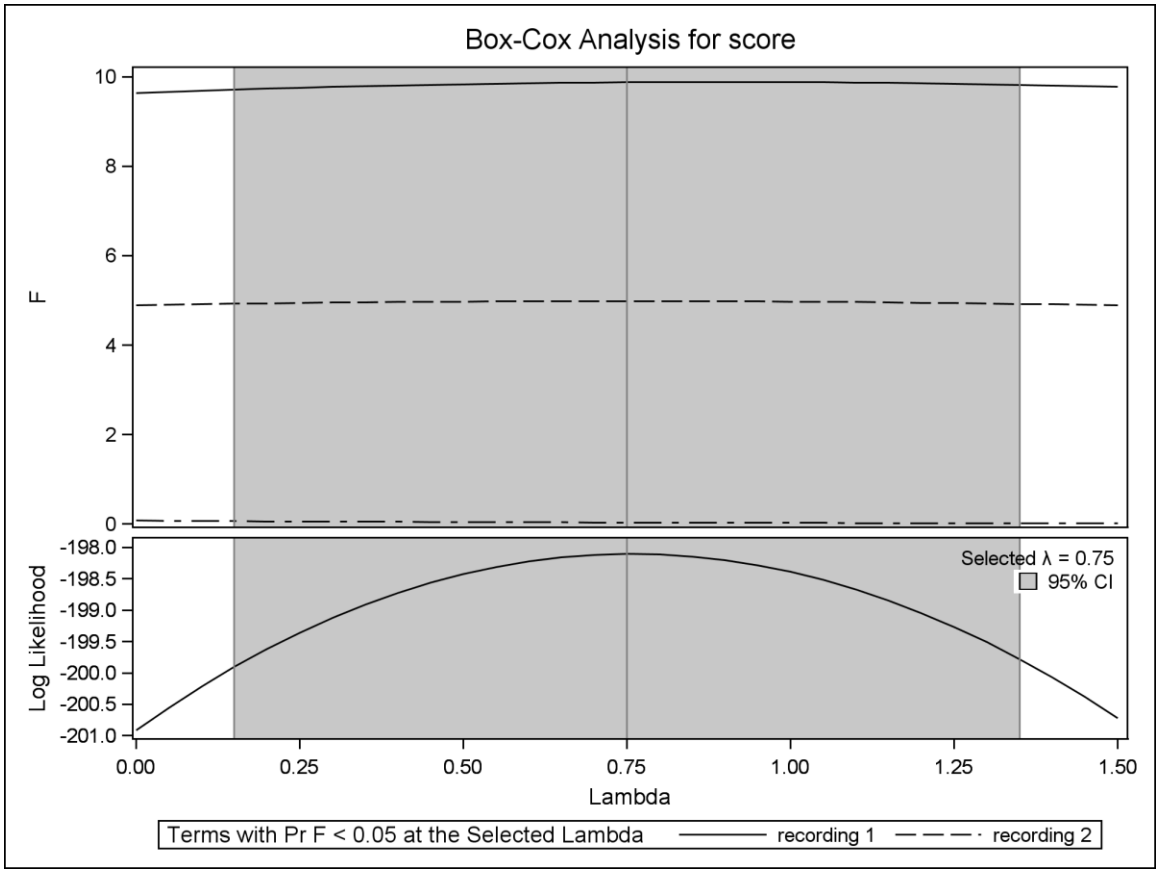
(SAS Output 1 continues on next page)

(SAS Output 1, continued)



```
proc transreg data=hearing;
  model boxcox(score / lambda=0 to 1.5 by 0.05)
     = class(recording);
  title1 'SAS Output 2';
run;
```

SAS Output 2



```
proc glm data=hearing;
     class recording;
     model score = recording;
     means recording / LSD DUNNETT('3') REGWQ;
     lsmeans recording / pdiff;
     title1 'SAS Output 3';
run;
```

SAS Output 3

t Tests (LSD) for score

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	92
Error Mean Square	62.37138
Critical Value of t	1.98609
Least Significant Difference	4.5279

Means with the same letter are not significantly different.

t Grouping	Mean	N	recording
A	32.750	24	1
A			
A	30.667	24	2
B	25.583	24	4
B			
B	25.250	24	3

(SAS Output 3 continues on next page)

(SAS Output 3, continued)

Dunnett's t Tests for score

Note: This test controls the Type I experimentwise error for comparisons of all treatments against a control.

Alpha	0.05
Error Degrees of Freedom	92
Error Mean Square	62.37138
Critical Value of Dunnett's t	2.38842
Minimum Significant Difference	5.4452

Comparisons significant at the 0.05 level are indicated by *.**

recording Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
1 - 3	7.500	2.055	12.945	***
2 - 3	5.417	-0.029	10.862	
4 - 3	0.333	-5.112	5.779	

(SAS Output 3 continues on next page)

(SAS Output 3, continued)

Ryan-Einot-Gabriel-Welsch Multiple Range Test for score

Note: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	92
Error Mean Square	62.37138

Number of Means	**2**	**3**	**4**
Critical Range	5.1831876	5.4310815	5.9654322

Means with the same letter are not significantly different.

REGWQ Grouping		**Mean**	**N**	**recording**
	A	32.750	24	1
	A			
B	A	30.667	24	2
B				
B		25.583	24	4
B				
B		25.250	24	3

```
proc glm data=hearing;
  class Accent Background;
  model score = Accent|Background;
  title1 'SAS Output 4';
run;
```

SAS Output 4

Class Level Information		
Class	**Levels**	**Values**
Accent	2	American British
Background	2	Music Static

Number of Observations Read	96
Number of Observations Used	96

Dependent Variable: score

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1003.458333	334.486111	[redacted]	0.0019
Error	92	5738.166667	62.371377		
Corrected Total	95	6741.625000			

R-Square	Coeff Var	Root MSE	score Mean
[redacted]	27.65008	7.897555	28.56250

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Accent	1	35.0416667	35.0416667	0.56	0.4554
Background	1	18.3750000	18.3750000	0.29	0.5886
Accent*Background	1	950.0416667	950.0416667	15.23	0.0002

(SAS Output 4 continues on next page)

(SAS Output 4, continued)