

Spring 2000 First Midterm Exam – Graduate Statistics

There are three questions to this exam. Each sub-question is worth 3 points.

Question A. Hearing loss in infants may have important consequences for the child's development. A researcher who is interested in self-development (i.e., the development of a concept of self and the development of appropriate relations to others) collects data on children with different types of hearing loss. The following variables are available for analysis:

**Hearing Status (H)** with levels Deaf, Hard of Hearing, and Normal Hearing

**Mother (M)** with levels Deaf or Normal Hearing

**Age (A)** in months

**Self Development (SD)**, a quantitative scale measuring self-development; this is the dependent variable

Using these variables and others you may construct from them (give specific definitions the first time you use a constructed variable) to provide Model C/A comparisons that would answer the following research questions.

1. Is self-development predictable from the child's age?
2. Does the relationship between self-development and the child's age decrease with age?
3. Assuming that the relationship between self-development and the child's age does decrease with age, a researcher hypothesizes that increasing age will provide no additional benefits at about age 4 years (48 months). Is this the case?
4. Is self-development related to the child's hearing status, controlling for the mother's hearing status? (In particular, answer whether self-development is related to any kind of hearing loss, either hard of hearing or deaf.)
5. Does the delay in self-development due to any kind of hearing loss depend on the mother's hearing status?
6. When controlling for age, is any kind of hearing loss related to the child's self-development?
7. In Question #6, is the relationship between the covariate age and self-development the same within each level of child's hearing status?

Question B. Data on 398 cars from the 1986 product year are gathered. These cars are either American (n = 249); European (n = 70); or Japanese (n = 79). The primary question concerns the prediction of gas mileage. For each car the following variables are measured:

|        |   |
|--------|---|
| MPG    | Miles per gallon                        |
| CYL    | Number of cylinders                     |
| WEIGHT | Vehicle weight in pounds                |
| ORIGIN | 1=American made; 2=European; 3=Japanese |

From these variables, the following additional variables are computed:

|       |   |  |
|-------|---|--|
| AVSO  | = | +2 if ORIGIN = 1; -1 if ORIGIN = 2 or 3            |
| EVSJ  | = | 0 if ORIGIN = 1; +1 if ORIGIN= 2; -1 if ORIGIN = 3 |
| CINT1 | = | AVSO*CYL;  |
| CINT2 | = | EVSJ*CYL;  |
| WINT1 | = | AVSO*WEIGHT;                                       |
| WINT2 | = | EVSJ*WEIGHT;                                       |

From the SAS output on the following pages, predicting MPG from various combinations of the other variables, answer the following questions.

1. Can we predict a vehicle's gas consumption (MPG) by knowing how many cylinders it has and its weight? (Present PRE, F\*, and interpret any meaningful parameter estimates.)
2. Are there country of origin differences in gas consumption, using the simplest model? Test whether American, European, and Japanese cars differ (give PRE and F\*) and, if they do, present the mean MPG's for cars from each country.
3. Is there a significant difference between the gas consumption of American and European cars? (Present SSR, PRE, and F\*).
4. Equating cars on number of cylinders and weight, is there still a country of origin difference in gas consumption? (Give PRE and F\*)
5. There may be differences between cars from the three regions in the relationships between the number of cylinders, the weight of the car, and gas consumption. What would the slopes for CYL and WEIGHT be if a model was estimated just for the data from the American cars, regressing MPG on CYL and WEIGHT?
6. Is CYL differentially predictive of MPG for American cars than for European or Japanese cars? (Give PRE, and F\*.)

Model: MODEL1  
 Dependent Variable: MPG

Analysis of Variance

| Source   | DF       | Sum of Squares | Mean Square | F Value | Prob>F |
|----------|----------|----------------|-------------|---------|--------|
| Model    | 2        | 16889.52736    | 8444.76368  | 453.030 | 0.0001 |
| Error    | 395      | 7363.04812     | 18.64063    |         |        |
| C Total  | 397      | 24252.57548    |             |         |        |
| Root MSE | 4.31748  | R-square       | 0.6964      |         |        |
| Dep Mean | 23.51457 | Adj R-sq       | 0.6949      |         |        |
| C.V.     | 18.36087 |                |             |         |        |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0:<br>Parameter=0 | Prob >  T |
|----------|----|--------------------|----------------|--------------------------|-----------|
| INTERCEP | 1  | 46.393702          | 0.79089059     | 58.660                   | 0.0001    |
| CYL      | 1  | -0.702508          | 0.28689761     | -2.449                   | 0.0148    |
| WEIGHT   | 1  | -0.006412          | 0.00057628     | -11.127                  | 0.0001    |

| Variable | DF | Type II SS  | Squared<br>Partial<br>Corr Type II | Tolerance  |
|----------|----|-------------|------------------------------------|------------|
| INTERCEP | 1  | 64142       | .                                  | .          |
| CYL      | 1  | 111.765893  | 0.01495233                         | 0.19715390 |
| WEIGHT   | 1  | 2307.923441 | 0.23864442                         | 0.19715390 |

Model: MODEL2  
 Dependent Variable: MPG

Analysis of Variance

| Source   | DF       | Sum of Squares | Mean Square | F Value | Prob>F |
|----------|----------|----------------|-------------|---------|--------|
| Model    | 2        | 8072.82066     | 4036.41033  | 98.542  | 0.0001 |
| Error    | 395      | 16179.75482    | 40.96140    |         |        |
| C Total  | 397      | 24252.57548    |             |         |        |
| Root MSE | 6.40011  | R-square       | 0.3329      |         |        |
| Dep Mean | 23.51457 | Adj R-sq       | 0.3295      |         |        |
| C.V.     | 27.21763 |                |             |         |        |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0:<br>Parameter=0 | Prob >  T |
|----------|----|--------------------|----------------|--------------------------|-----------|
| INTERCEP | 1  | 26.141865          | 0.37537616     | 69.642                   | 0.0001    |
| AVSO     | 1  | -3.029166          | 0.22121359     | -13.693                  | 0.0001    |
| EVJSJ    | 1  | -1.279602          | 0.52527653     | -2.436                   | 0.0153    |

| Variable | DF | Type II SS  | Squared<br>Partial<br>Corr Type II | Tolerance  |
|----------|----|-------------|------------------------------------|------------|
| INTERCEP | 1  | 198662      | .                                  | .          |
| AVSO     | 1  | 7680.637288 | 0.32189904                         | 0.99771428 |
| EVSJ     | 1  | 243.079755  | 0.01480133                         | 0.99771428 |

Model: MODEL3  
Dependent Variable: MPG

Analysis of Variance

| Source  | DF  | Sum of<br>Squares | Mean<br>Square | F Value | Prob>F |
|---------|-----|-------------------|----------------|---------|--------|
| Model   | 4   | 17093.65072       | 4273.41268     | 234.595 | 0.0001 |
| Error   | 393 | 7158.92475        | 18.21609       |         |        |
| C Total | 397 | 24252.57548       |                |         |        |

|          |          |          |        |
|----------|----------|----------|--------|
| Root MSE | 4.26803  | R-square | 0.7048 |
| Dep Mean | 23.51457 | Adj R-sq | 0.7018 |
| C.V.     | 18.15058 |          |        |

Parameter Estimates

| Variable | DF | Parameter<br>Estimate | Standard<br>Error | T for H0:<br>Parameter=0 | Prob >  T |
|----------|----|-----------------------|-------------------|--------------------------|-----------|
| INTERCEP | 1  | 45.095235             | 0.88794106        | 50.786                   | 0.0001    |
| CYL      | 1  | -0.611217             | 0.29095957        | -2.101                   | 0.0363    |
| WEIGHT   | 1  | -0.005994             | 0.00058354        | -10.272                  | 0.0001    |
| AVSO     | 1  | -0.519929             | 0.18739121        | -2.775                   | 0.0058    |
| EVSJ     | 1  | -0.656888             | 0.35417627        | -1.855                   | 0.0644    |

| Variable | DF | Type II SS  | Squared<br>Partial<br>Corr Type II | Tolerance  |
|----------|----|-------------|------------------------------------|------------|
| INTERCEP | 1  | 46984       | .                                  | .          |
| CYL      | 1  | 80.386199   | 0.01110412                         | 0.18732194 |
| WEIGHT   | 1  | 1922.123823 | 0.21166320                         | 0.18789395 |
| AVSO     | 1  | 140.231231  | 0.01921198                         | 0.61831779 |
| EVSJ     | 1  | 62.661143   | 0.00867692                         | 0.97594120 |

Model: MODEL4  
Dependent Variable: MPG

Analysis of Variance

| Source  | DF  | Sum of<br>Squares | Mean<br>Square | F Value | Prob>F |
|---------|-----|-------------------|----------------|---------|--------|
| Model   | 8   | 17483.58315       | 2185.44789     | 125.593 | 0.0001 |
| Error   | 389 | 6768.99233        | 17.40101       |         |        |
| C Total | 397 | 24252.57548       |                |         |        |

|          |          |          |        |
|----------|----------|----------|--------|
| Root MSE | 4.17145  | R-square | 0.7209 |
| Dep Mean | 23.51457 | Adj R-sq | 0.7152 |
| C.V.     | 17.73986 |          |        |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0:<br>Parameter=0 | Prob >  T |
|----------|----|--------------------|----------------|--------------------------|-----------|
| INTERCEP | 1  | 45.792088          | 1.93338444     | 23.685                   | 0.0001    |
| CYL      | 1  | 0.344554           | 0.52251567     | 0.659                    | 0.5100    |
| WEIGHT   | 1  | -0.008083          | 0.00073898     | -10.937                  | 0.0001    |
| AVSO     | 1  | -1.357247          | 1.02223995     | -1.328                   | 0.1850    |
| EVSJ     | 1  | -3.234272          | 2.84235864     | -1.138                   | 0.2559    |
| CINT1    | 1  | -0.845515          | 0.27867165     | -3.034                   | 0.0026    |
| CINT2    | 1  | -0.656280          | 0.76556790     | -0.857                   | 0.3918    |
| WINT1    | 1  | 0.001873           | 0.00042144     | 4.444                    | 0.0001    |
| WINT2    | 1  | 0.002427           | 0.00105140     | 2.309                    | 0.0215    |

| Variable | DF | Type II SS  | Squared<br>Partial<br>Corr Type II | Tolerance  |
|----------|----|-------------|------------------------------------|------------|
| INTERCEP | 1  | 9761.552260 | .                                  | .          |
| CYL      | 1  | 7.566430    | 0.00111656                         | 0.05548486 |
| WEIGHT   | 1  | 2081.660527 | 0.23519853                         | 0.11192175 |
| AVSO     | 1  | 30.675158   | 0.00451127                         | 0.01984832 |
| EVSJ     | 1  | 22.530448   | 0.00331744                         | 0.01447518 |
| CINT1    | 1  | 160.188468  | 0.02311795                         | 0.00784866 |
| CINT2    | 1  | 12.787493   | 0.00188557                         | 0.01150649 |
| WINT1    | 1  | 343.671405  | 0.04831824                         | 0.01184588 |
| WINT2    | 1  | 92.755435   | 0.01351776                         | 0.01907236 |

Question C. A clinical psychologist studied the effectiveness of various therapies for reducing cigarette smoking. He randomly assigned 24 smokers to either a verbal therapy, a drug therapy or a control condition (in which participants just checked in with the researcher weekly). Within each condition of therapy, participants were randomly assigned to receive the therapy (or control condition) for either one or three weeks. After therapy, the number of cigarettes smoked in the following week was recorded for each participant. Because the psychologist was aware that some people smoke more when they are stressed, the psychologist also assessed the number of stressful events participants experienced each day. From this he calculated a daily average of stressful events each participant experienced during the week.

There are data available from each smoker on the following variables:

**THERNO**                    -1 if verbal or drug therapy, +2 if control condition  
**VERBDRUG**                +1 if verbal therapy, -1 if drug therapy, 0 if control  
**LENGTH**                    -1 if one week, +1 if three weeks  
**STRESS**                    average number of daily stressful events  
**CIGS**                        # of cigarettes smoked during the week

Below are the number of smokers in each condition, the means of the number of cigarettes smoked, and the average stress experienced per condition:

|                        | <b>n</b> | <b>CIGS</b> | <b>STRESS</b> |
|------------------------|----------|-------------|---------------|
| <b>Control Therapy</b> |          |             |               |
| 1 week                 | 4        | 122         | 6.7           |
| 3 weeks                | 4        | 122.5       | 5.93          |
|                        |          |             |               |
| <b>Verbal Therapy</b>  |          |             |               |
| 1 week                 | 4        | 100         | 6.95          |
| 3 weeks                | 4        | 80          | 6.30          |
|                        |          |             |               |
| <b>Drug Therapy</b>    |          |             |               |
| 1 week                 | 4        | 110         | 6.43          |
| 3 weeks                | 4        | 90          | 6.01          |

Possible Interactions:

TLENGTH                    THERNO\*LENGTH  
VDLENGTH                    VERBDRUG\*LENGTH  
COVTHER                    STRESS\*THERNO  
COVDRUG                    STRESS\*VERBDRUG  
COLENGTH                    STRESS\*LENGTH  
COTLENG                    STRESS\*THERNO\*LENGTH  
COVLENG                    STRESS\*VERBDRUG\*LENGTH

Based on the output on the following pages, answer the following questions:

1. Without considering the effects of stress, is there a main effect of therapy (verbal versus drug versus control)? Provide the SSR, PRE, F\* and p.
2. Is stress related to the number of cigarettes smoked over and above the effects of therapy type and duration? Give PRE and F\*.
3. Once the average number of stressful events are controlled, are there differences in the number of cigarettes smoked by people who had verbal versus drug therapies? Provide PRE and F\*.
4. Once stress is controlled (based on model 2), what is the adjusted mean for people who receive the drug therapy for one week?
5. From Model 3, interpret the coefficient for the verbal versus drug therapy by stress interaction (i.e., COVDRUG).

Model: MODEL1

Dependent Variable: CIGS

Analysis of Variance

| Source   | DF       | Sum of Squares | Mean Square | F Value | Prob>F |
|----------|----------|----------------|-------------|---------|--------|
| Model    | 5        | 18157.33333    | 3631.46667  | 8.734   | 0.0002 |
| Error    | 18       | 7484.00000     | 415.77778   |         |        |
| C Total  | 23       | 25641.33333    |             |         |        |
| Root MSE | 20.39063 | R-square       | 0.7081      |         |        |
| Dep Mean | 91.33333 | Adj R-sq       | 0.6271      |         |        |
| C.V.     | 22.32551 |                |             |         |        |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0: Parameter=0 | Prob >  T |
|----------|----|--------------------|----------------|-----------------------|-----------|
| INTERCEP | 1  | 91.333333          | 4.16221985     | 21.943                | 0.0001    |
| THERNO   | 1  | 11.083333          | 2.94313388     | 3.766                 | 0.0014    |
| VERBDRUG | 1  | -9.750000          | 5.09765741     | -1.913                | 0.0718    |
| LENGTH   | 1  | -19.333333         | 4.16221985     | -4.645                | 0.0002    |
| TLENGTH  | 1  | 5.416667           | 2.94313388     | 1.840                 | 0.0823    |
| VDLENGTH | 1  | -4.750000          | 5.09765741     | -0.932                | 0.3638    |

| Variable | DF | Type II SS  | Squared Partial Corr Type II | Tolerance  |
|----------|----|-------------|------------------------------|------------|
| INTERCEP | 1  | 200203      | .                            | .          |
| THERNO   | 1  | 5896.333333 | 0.44067163                   | 1.00000000 |
| VERBDRUG | 1  | 1521.000000 | 0.16890616                   | 1.00000000 |
| LENGTH   | 1  | 8970.666667 | 0.54517462                   | 1.00000000 |
| TLENGTH  | 1  | 1408.333333 | 0.15837613                   | 1.00000000 |
| VDLENGTH | 1  | 361.000000  | 0.04601657                   | 1.00000000 |

Model: MODEL2  
 Dependent Variable: CIGS

Analysis of Variance

| Source   | DF       | Sum of Squares | Mean Square | F Value | Prob>F |
|----------|----------|----------------|-------------|---------|--------|
| Model    | 6        | 19825.87733    | 3304.31289  | 9.659   | 0.0001 |
| Error    | 17       | 5815.45600     | 342.08565   |         |        |
| C Total  | 23       | 25641.33333    |             |         |        |
| Root MSE | 18.49556 | R-square       | 0.7732      |         |        |
| Dep Mean | 91.33333 | Adj R-sq       | 0.6932      |         |        |
| C.V.     | 20.25061 |                |             |         |        |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0: Parameter=0 | Prob >  T |
|----------|----|--------------------|----------------|-----------------------|-----------|
| INTERCEP | 1  | 32.405333          | 26.94789371    | 1.203                 | 0.2456    |
| STRESS   | 1  | 9.280000           | 4.20190830     | 2.209                 | 0.0412    |
| THERNO   | 1  | 12.707333          | 2.76902516     | 4.589                 | 0.0003    |
| VERBDRUG | 1  | -7.198000          | 4.76608754     | -1.510                | 0.1493    |
| LENGTH   | 1  | -16.162667         | 4.03914165     | -4.002                | 0.0009    |
| TLENGTH  | 1  | 7.079333           | 2.77372588     | 2.552                 | 0.0206    |
| VDLENGTH | 1  | 0.238000           | 5.14599760     | 0.046                 | 0.9637    |

| Variable | DF | Type II SS  | Squared Partial Corr Type II | Tolerance  |
|----------|----|-------------|------------------------------|------------|
| INTERCEP | 1  | 494.672979  | .                            | .          |
| STRESS   | 1  | 1668.544000 | 0.22294816                   | 0.62459703 |
| THERNO   | 1  | 7204.268554 | 0.55333494                   | 0.92947949 |
| VERBDRUG | 1  | 780.251311  | 0.11829684                   | 0.94121933 |
| LENGTH   | 1  | 5477.504168 | 0.48503706                   | 0.87366602 |
| TLENGTH  | 1  | 2228.396663 | 0.27703101                   | 0.92633173 |
| VDLENGTH | 1  | 0.731728    | 0.00012581                   | 0.80737577 |

Model: MODEL3  
 Dependent Variable: CIGS

Analysis of Variance

| Source   | DF       | Sum of Squares | Mean Square | F Value | Prob>F |
|----------|----------|----------------|-------------|---------|--------|
| Model    | 11       | 22847.86153    | 2077.07832  | 8.923   | 0.0003 |
| Error    | 12       | 2793.47180     | 232.78932   |         |        |
| C Total  | 23       | 25641.33333    |             |         |        |
| Root MSE | 15.25743 | R-square       | 0.8911      |         |        |
| Dep Mean | 91.33333 | Adj R-sq       | 0.7912      |         |        |
| C.V.     | 16.70522 |                |             |         |        |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0:<br>Parameter=0 | Prob >  T |
|----------|----|--------------------|----------------|--------------------------|-----------|
| INTERCEP | 1  | 37.839099          | 24.60610648    | 1.538                    | 0.1500    |
| STRESS   | 1  | 8.707504           | 3.80973664     | 2.286                    | 0.0413    |
| THERNO   | 1  | -7.065676          | 16.96922596    | -0.416                   | 0.6845    |
| VERBDRUG | 1  | -95.250390         | 30.86288287    | -3.086                   | 0.0094    |
| LENGTH   | 1  | -49.156399         | 24.60610648    | -1.998                   | 0.0689    |
| TLENGTH  | 1  | 37.646359          | 16.96922596    | 2.219                    | 0.0466    |
| VDLENGTH | 1  | 39.789218          | 30.86288287    | 1.289                    | 0.2216    |
| COVTHER  | 1  | 2.890800           | 2.63151966     | 1.099                    | 0.2935    |
| COVDRUG  | 1  | 14.082047          | 4.77153986     | 2.951                    | 0.0121    |
| COLENGTH | 1  | 5.693201           | 3.80973664     | 1.494                    | 0.1609    |
| COTLENG  | 1  | -4.887763          | 2.63151966     | -1.857                   | 0.0880    |
| COVLENG  | 1  | -5.550137          | 4.77153986     | -1.163                   | 0.2674    |

| Variable | DF | Type II SS  | Squared<br>Partial<br>Corr Type II | Tolerance  |
|----------|----|-------------|------------------------------------|------------|
| INTERCEP | 1  | 550.501904  | .                                  | .          |
| STRESS   | 1  | 1216.075476 | 0.30329496                         | 0.51704857 |
| THERNO   | 1  | 40.359554   | 0.01424205                         | 0.01684216 |
| VERBDRUG | 1  | 2217.295566 | 0.44250619                         | 0.01527461 |
| LENGTH   | 1  | 929.046317  | 0.24957469                         | 0.01602013 |
| TLENGTH  | 1  | 1145.737015 | 0.29085460                         | 0.01684216 |
| VDLENGTH | 1  | 386.919733  | 0.12165789                         | 0.01527461 |
| COVTHER  | 1  | 280.922078  | 0.09137478                         | 0.01773797 |
| COVDRUG  | 1  | 2027.577617 | 0.42056769                         | 0.01464477 |
| COLENGTH | 1  | 519.859659  | 0.15689938                         | 0.01610393 |
| COTLENG  | 1  | 803.100705  | 0.22329613                         | 0.01773930 |
| COVLENG  | 1  | 314.958476  | 0.10132396                         | 0.01469265 |