

## 7

# Interactions—getting more complex

## 7.2 Analysis of factorial experiments

The convention used by SAS to represent interactions is the \* sign, as in the main text. When using menus, interactions make the use of the 'Model' button necessary, and in the resulting subdialog box a new kind of operation is required. Two variables are selected simultaneously, and when they are moved together with the 'Cross' button, it is their interaction that is included in the model. To select two variables simultaneously, hold the mouse button down and drag across the variable names until both are highlighted. We use the convention (VARIETY & SOWRATE) to indicate that the variables should be selected together. In this first example, a step-by-step approach is used that moves VARIETY then SOWRATE and then the interaction between them.

### SAS COMMANDS FOR BOX 7.2 A factorial ANOVA of the yield data

Commands `proc glm data=gandh.Chapter7;`  
`class BLOCK VARIETY SOWRATE;`  
`model YIELD =BLOCK VARIETY SOWRATE VARIETY*SOWRATE /SS3;`  
`run;`

Menu route Statistics > Anova > Linear Models...

YIELD → Dependent

BLOCK VARIETY SOWRATE → Class

Model

Independent → Effects in Model

BLOCK → Add

VARIETY → Add

SOWRATE → Add

(VARIETY & SOWRATE) → Cross

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There is a shorthand method, which is to select VARIETY and SOWRATE and to move them with the ‘Factorial’ button. (Use of the shortcut means that SAS chooses the order of the variables, so it will not always be suitable.) In the command line route, there is also a shorthand. As in the main text, the command route allows us to write VARIETY|SOWRATE as a shorthand for ‘VARIETY SOWRATE VARIETY\*SOWRATE’.

ALTERNATIVE SAS COMMANDS FOR BOX 7.2 <b>A factorial ANOVA of the yield data</b>	
Commands	<pre>proc glm data=gandh.Chapter7;     class BLOCK VARIETY SOWRATE;     model YIELD =BLOCK VARIETY SOWRATE / SS3; run;</pre>
Menu route	<p>Statistics &gt; Anova &gt; Linear Models...</p> <p>YIELD → Dependent</p> <p>BLOCK VARIETY SOWRATE → Class</p> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin: 5px;">Model</div> <p>Independent → Effects in Model</p> <p>BLOCK → Add</p> <p>(VARIETY &amp; SOWRATE) → Factorial</p>

These sets of commands will provide you with the output as shown below:

SAS OUTPUT FOR BOX 7.2 <b>A factorial ANOVA of the yield data</b>						
The GLM Procedure						
Dependent Variable: YIELD						
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F	
Model	9	8.47127129	0.94125237	2.48	0.0617	
Error	14	5.30689233	0.37906374			
Corrected Total	23	13.77816363				
	R-Square	Coeff Var	Root MSE	YIELD Mean		
	0.614833	7.212447	0.615682	8.536375		
Source	DF	Type III SS	Mean Square	F Value	Pr > F	
BLOCK	2	0.39366100	0.19683050	0.52	0.6060	
VARIETY	1	2.14741837	2.14741837	5.67	0.0321	
SOWRATE	3	5.87359012	1.95786337	5.16	0.0130	
VARIETY*SOWRATE	3	0.05660179	0.01886726	0.05	0.9847	

In future we will use the shorthand in the command line route for brevity. However, we will use the step-by-step route in the menus because this allows us to determine the order of terms in the model.

## 7.4 Presenting the results

### Factorial experiments with insignificant interactions

If the interaction is not significant, as is the case with the *wheat* dataset, you may wish to display the means for the main effects only. These can be obtained by requesting the coefficient table with the following commands.

#### SAS COMMANDS FOR BOX 7.3 The coefficients table from the factorial analysis of Box 7.2

```
Commands  proc glm data=gandh.Chapter7;
           class BLOCK VARIETY SOWRATE;
           model YIELD =BLOCK VARIETY|SOWRATE / SS3 solution;
           run;
```

```
Menu route  Statistics > Anova > Linear Models...
           YIELD → Dependent
           BLOCK VARIETY SOWRATE → Class
           Model
           Independent → Effects in Model
           BLOCK → Add
           VARIETY → Add
           SOWRATE → Add
           (VARIETY & SOWRATE) → Cross
           Statistics...
            Parameter Estimates
```

In addition to the ANOVA table, this will give you the coefficient table, or 'solution' as SAS calls it. SAS will give you the coefficients for the full model. We illustrate here how you can use this information to obtain fitted values for the main effects.

## SAS OUTPUT FOR BOX 7.3 The coefficients table from the factorial analysis of Box 7.2

Parameter		Estimate	Standard Error	t Value	Pr >  t
Intercept		9.002416667 B	0.39742071	22.65	<.0001
BLOCK	1	0.011500000 B	0.30784076	0.04	0.9707
BLOCK	2	0.277250000 B	0.30784076	0.90	0.3830
BLOCK	3	0.000000000 B	.	.	.
VARIETY	1	0.536666667 B	0.50270186	1.07	0.3038
VARIETY	2	0.000000000 B	.	.	.
SOWRATE	1	-1.186000000 B	0.50270186	-2.36	0.0334
SOWRATE	2	-1.358333333 B	0.50270186	-2.70	0.0172
SOWRATE	3	-0.901333333 B	0.50270186	-1.79	0.0946
SOWRATE	4	0.000000000 B	.	.	.
VARIETY*SOWRATE	1 1	0.150000000 B	0.71092779	0.21	0.8359
VARIETY*SOWRATE	1 2	0.161666667 B	0.71092779	0.23	0.8234
VARIETY*SOWRATE	1 3	-0.065333333 B	0.71092779	-0.09	0.9281
VARIETY*SOWRATE	1 4	0.000000000 B	.	.	.
VARIETY*SOWRATE	2 1	0.000000000 B	.	.	.
VARIETY*SOWRATE	2 2	0.000000000 B	.	.	.
VARIETY*SOWRATE	2 3	0.000000000 B	.	.	.
VARIETY*SOWRATE	2 4	0.000000000 B	.	.	.

In the Table below, we have extracted the coefficients for each variable, and at the bottom of the Table, have calculated the average coefficient (except for the interaction coefficients, which we use differently).

Intercept	Block	Variety	Sowrate	Interaction
9.0024	1	0.0115	1	1 1
	2	0.2773	2	1 2
	3	0	3	1 3
			4	1 4
				2 1
				2 2
				2 3
				2 4
	Av	0.0963	0.2684	-0.8615

To calculate the aliased coefficients, we first follow the same steps as we did when there were no interactions: namely we calculated an adjusted mean, by summing the intercept, and the average coefficients for the other variables. For example, for sowrate 4 this is:  $9.0024 + 0.0963 + 0.2684 = 9.367$ . Second, we add to this the coefficient for level 4 of sowrate, which of course is zero as it is aliased. Third, we add to this the average of the coefficients for the interactions of sowrate 4 with other levels—which in this case is also zero. Thus the mean for sowrate 4 is 9.367 (as in Box 7.4 of the main text). SAS Box 7.4 below completes this for all levels of SOWRATE and VARIETY, producing the same values as found in Box 7.4 of the main text.

CALCULATIONS FROM SAS OUTPUT TO OBTAIN THE MEANS AS IN BOX 7.4							
		Intercept	Average coefficients for other variables, and coefficient for the level of the particular variable			Average Coefficients for interaction terms	Total
			BLOCK	VARIETY	SOWRATE		
Sowrate	1	9.0024	0.0963	0.2684	-1.1860	0.075	8.256
	2	9.0024	0.0963	0.2684	-1.3583	0.0808	8.089
	3	9.0024	0.0963	0.2684	-0.9013	-0.03265	8.433
	4	9.0024	0.0963	0.2684	-	0	9.367
Variety	1	9.0024	0.0963	0.5367	-0.8614	0.0616	8.835
	2	9.0024	0.0963	-	-0.8614	0	8.237

Alternatively, the means for the main effects can be obtained directly, using the following commands. We have chosen to ignore BLOCK as we are interested only in the means for the two treatment main effects in this instance.

SAS COMMANDS FOR BOX 7.4 <b>Obtaining the means for the main effects only</b>	
Commands	<pre>proc glm data=gandh.Chapter7;   class BLOCK VARIETY SOWRATE;   model YIELD =BLOCK VARIETY SOWRATE / SS3;   lsmeans VARIETY SOWRATE; run;</pre>
Menu route	<p>Statistics &gt; Anova &gt; Linear Models...</p> <p>YIELD → Dependent</p> <p>BLOCK VARIETY SOWRATE → Class</p> <p><b>Model</b></p> <p>Independent → Effects in Model</p> <p>BLOCK → Add</p> <p>VARIETY → Add</p> <p>SOWRATE → Add</p> <p>(VARIETY &amp; SOWRATE) → Cross</p> <p><b>Means</b> with LS Means tab</p> <p>VARIETY → LS Mean</p> <p>SOWRATE → LS Mean</p>

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In addition to the ANOVA table, this will give you the following output:

SAS OUTPUT FOR BOX 7.4 Summarising the results when the interaction is not significant			
The GLM Procedure Least Squares Means			
VARIETY	YIELD	LSMEAN	
1		8.83550000	
2		8.23725000	
SOWRATE	YIELD	LSMEAN	
1		8.25600000	
2		8.08950000	
3		8.43300000	
4		9.36700000	

## Factorial experiments with significant interactions

The *tulips* dataset provides an example of an experiment of factorial design with a significant interaction. The coefficient table may be obtained in the usual way:

SAS COMMANDS FOR BOX 7.5 Analysing a factorial experiment with a significant interaction	
Commands	<pre>proc glm data=gandh.Chapter7;   class BED WATER SHADE;   model BLOOMS = BED WATER SHADE / solution; run;</pre>
Menu route	Statistics > Anova > Linear Models...  BLOOMS → Dependent  BED WATER SHADE → Class  <input type="text" value="Model"/>  Independent → Effects in Model  BED → Add  WATER → Add  SHADE → Add  (WATER & SHADE) → Cross  <input type="text" value="Statistics"/> <input checked="" type="checkbox"/> Parameter Estimates <input checked="" type="checkbox"/> Type 1

SAS OUTPUT FOR BOX 7.5 **Analysing a factorial experiment with a significant interaction**

The GLM Procedure

Dependent Variable: BLOOMS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	10	194871.2133	19487.1213	10.95	<.0001
Error	16	28476.8351	1779.8022		
Corrected Total	26	223348.0484			

  

	R-Square	Coeff Var	Root MSE	BLOOMS Mean
	0.872500	32.70524	42.18770	128.9937

  

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BED	2	13811.3501	6905.6750	3.88	0.0423
WATER	2	103625.7870	51812.8935	29.11	<.0001
SHADE	2	36375.9368	18187.9684	10.22	0.0014
WATER*SHADE	4	41058.1394	10264.5349	5.77	0.0045

  

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BED	2	13811.3501	6905.6750	3.88	0.0423
WATER	2	103625.7870	51812.8935	29.11	<.0001
SHADE	2	36375.9368	18187.9684	10.22	0.0014
WATER*SHADE	4	41058.1394	10264.5349	5.77	0.0045

  

Parameter	Estimate	Standard Error	t Value	Pr >  t
Intercept	153.1051852 B	26.92776631	5.69	<.0001
BED 1	-50.1522222 B	19.88747343	-2.52	0.0227
BED 2	-4.6933333 B	19.88747343	-0.24	0.8164
BED 3	0.0000000 B	.	.	.
WATER 1	-55.6033333 B	34.44611441	-1.61	0.1260
WATER 2	-57.1933333 B	34.44611441	-1.66	0.1163
WATER 3	0.0000000 B	.	.	.
SHADE 1	162.2266667 B	34.44611441	4.71	0.0002
SHADE 2	41.9200000 B	34.44611441	1.22	0.2413
SHADE 3	0.0000000 B	.	.	.
WATER*SHADE 1 1	-211.4066667 B	48.71416217	-4.34	0.0005
WATER*SHADE 1 2	-76.5933333 B	48.71416217	-1.57	0.1354
WATER*SHADE 1 3	0.0000000 B	.	.	.
WATER*SHADE 2 1	-25.6566667 B	48.71416217	-0.53	0.6056
WATER*SHADE 2 2	-12.8600000 B	48.71416217	-0.26	0.7952
WATER*SHADE 2 3	0.0000000 B	.	.	.
WATER*SHADE 3 1	0.0000000 B	.	.	.
WATER*SHADE 3 2	0.0000000 B	.	.	.
WATER*SHADE 3 3	0.0000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

The means for all combinations of WATER and SHADE can be calculated from the coefficient table as described in the table below. In essence, the calculations of the fitted values are much easier—the only variable we adjust for in this instance is BED. As we are interested in the means for each level of WATER and SHADE (because the interaction is significant), we simply sum the values for these coefficients.

## CALCULATING MEANS WITH SIGNIFICANT INTERACTIONS: LINKING SAS OUTPUT WITH BOX 7.6

WATER/SHADE Level	Intercept	BLOCK (average coefficient)	WATER (relevant coefficient)	SHADE (relevant coefficient)	Interaction (relevant coefficient)	Total
1 1	153.1053	-18.2819	-55.6033	162.2267	-211.4067	30.04
1 2	153.1053	-18.2819	-55.6033	41.9200	-76.5933	44.55
1 3	153.1053	-18.2819	-55.6033	0	0	79.22
2 1	153.1053	-18.2819	-57.1933	162.2267	-25.6567	214.20
2 2	153.1053	-18.2819	-57.1933	41.9200	-12.8600	106.69
2 3	153.1053	-18.2819	-57.1933	0	0	77.63
3 1	153.1053	-18.2819	0	162.2267	0	297.05
3 2	153.1053	-18.2819	0	41.9200	0	176.74
3 3	153.1053	-18.2819	0	0	0	134.82

To obtain these means directly, use the following commands:

SAS COMMANDS FOR BOX 7.6 **Summarising the results with a significant interaction**

```
Commands  proc glm data=gandh.Chapter7;
           class BED WATER SHADE;
           model BLOOMS = BED WATER|SHADE;
           lsmeans WATER*SHADE;
           run;
```

Menu route Statistics > Anova > Linear Models...

BLOOMS → Dependent

BED WATER SHADE → Class

Independent → Effects in Model

BED → Add

WATER → Add

SHADE → Add

(WATER & SHADE) → Cross

with LS Means tab

(WATER\*SHADE) → LS Mean

**SAS OUTPUT FOR BOX 7.6 Summarising the results with a significant interaction**

---

The GLM Procedure		
Least Squares Means		
WATER	SHADE	BLOOMS LSMEAN
1	1	30.040000
1	2	44.546667
1	3	79.220000
2	1	214.200000
2	2	106.690000
2	3	77.630000
3	1	297.050000
3	2	176.743333
3	3	134.823333

## 7.5 Extending the concept of interactions to continuous variables

### Mixing continuous and categorical variables

To include interactions between continuous and categorical variables, the same symbols and commands are used. This is illustrated with the *leprosy* dataset.

**SAS COMMANDS FOR BOX 7.7**  
**Analysing interactions with categorical and continuous variables: the leprosy dataset**

---

Commands `proc glm data=gandh.Chapter7;`  
`class TREATMT;`  
`model BACAFTER = BACBEF|TREATMT /solution;`  
`run;`

---

Menu route `Statistics > Anova > Linear Models...`

- BACAFTER → Dependent
- BACBEF → Quantitative
- TREATMT → Class

Model

- Independent → Effects in Model
- BACBEF → Add
- TREATMT → Add
- (BACBEF & TREATMT) → Cross

Statistics

- Parameter Estimates
- Type 1

**SAS OUTPUT FOR BOX 7.7**  
**Analysing interactions with categorical and continuous variables: the leprosy dataset**

---

The GLM Procedure

Dependent Variable: BACAFTER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	672.077002	134.415400	8.51	<.0001
Error	24	378.902291	15.787595		
Corrected Total	29	1050.979292			

  

	R-Square	Coef Var	Root MSE	BACAFTER Mean
	0.639477	40.24349	3.973361	9.873300

  

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BACBEF	1	587.4800981	587.4800981	37.21	<.0001
TREATMT	2	83.3473802	41.6736901	2.64	0.0920
BACBEF*TREATMT	2	1.2495233	0.6247616	0.04	0.9613

  

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BACBEF	1	482.6300200	482.6300200	30.57	<.0001
TREATMT	2	5.8268989	2.9134494	0.18	0.8327
BACBEF*TREATMT	2	1.2495233	0.6247616	0.04	0.9613

  

Parameter	Estimate	Standard Error	t Value	Pr >  t
Intercept	1.716475643 B	4.04551438	0.42	0.6751
BACBEF	0.933828434 B	0.33259318	2.81	0.0098
TREATMT 1	-2.788690141 B	4.89496647	-0.57	0.5742
TREATMT 2	-2.738578697 B	5.17643190	-0.53	0.6016
TREATMT 3	0.000000000 B	.	.	.
BACBEF*TREATMT 1	-0.105508555 B	0.41799140	-0.25	0.8029
BACBEF*TREATMT 2	-0.027764141 B	0.41083689	-0.07	0.9467
BACBEF*TREATMT 3	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

The rules to obtain the fitted value equations from the coefficients are a simple extension of the previous example. Here, we have calculated the lines including the interaction (even though it is not significant).

**USING THE SAS COEFFICIENTS TO PRODUCE THE FITTED VALUE EQUATIONS OF TABLE 7.3**

---

	Intercept	BACBEF	TREATMT	Interaction	Fitted Line: BACAFTER=
TREATMT 1	1.7165	0.9338	-2.7887	-0.1055	-1.072 + 0.8283*BACBEF
TREATMT 2	1.7165	0.9338	-2.7385	-0.0278	-1.022 + 0.906*BACBEF
TREATMT 3	1.7165	0.9338	0	0	1.716 + 0.9338*BACBEF

To compare the three treatments, there is the extra complication of the covariate BACBEF in the model. However, if you request the three treatment means with the same commands, SAS will adjust them for the mean value of BACBEF (for details see main text).

**SAS COMMANDS FOR BOX 7.8**  
**Obtaining adjusted means to compare treatments, when the model contains a covariate**

---

Commands    `proc glm data=gandh.Chapter7;`  
                  `class TREATMT;`  
                  `model BACAFTER = BACBEF|TREATMT / SS3;`  
                  `lsmeans TREATMT;`  
                  `run;`

---

Menu route    Statistics > Anova > Linear Models...

                  YIELD → Dependent

                  BACBEF → Quantitative

                  TREATMT → Class

                  Model

                  Independent → Effects in Model

                  BACBEF → Add

                  TREATMT → Add

                  (BACBEF & TREATMT) → Cross

                  Means            with LSMeans tab

                  TREATMT → LSMean

**SAS OUTPUT FOR BOX 7.8**  
**Obtaining adjusted means to compare treatments, when the model contains a covariate**

---

The GLM Procedure	
Least Squares Means	
TREATMT	BACAFTER LSMEAN
1	8.2007437
2	9.1211961
3	12.1705916

The means produced by SAS are automatically adjusted. By requesting the means for treatment, it is noted by SAS that a covariate is involved, so the treatment means are automatically adjusted on the basis that the covariate takes its mean value. The mean value of the covariate could be found using PROC UNIVARIATE or PROC MEANS (see SAS supplement for Chapter 1).

The analysis of the *Great tits* dataset uses the same commands, so we move on to the next section.

**Interactions between continuous variables**

To test for an interaction between two continuous variables, the same commands and symbols are used, as illustrated with the *trees* dataset.

**SAS COMMANDS FOR BOX 7.10 Testing for interactions between two continuous variables**

Commands `proc glm data=gandh.Chapter7;`  
`model VOLUME = DIAMETER|HEIGHT / solution;`  
`run;`

Menu route Statistics > Anova > Linear Models...

VOLUME → Dependent

DIAMETER HEIGHT → Quantitative

Model

Independent → Effects in Model

DIAMETER → Add

HEIGHT → Add

(DIAMETER & HEIGHT) → Cross

Statistics...

Type 1

Parameter Estimates

SAS OUTPUT FOR BOX 7.10 **Testing for interactions between two continuous variables**

The GLM Procedure

Dependent Variable: VOLUME

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	7908.005302	2636.001767	359.31	<.0001
Error	27	198.078569	7.336243		
Corrected Total	30	8106.083871			

  

R-Square	Coef Var	Root MSE	VOLUME Mean
0.975564	8.977339	2.708550	30.17097

  

Source	DF	Type I SS	Mean Square	F Value	Pr > F
DIAMETER	1	7581.781332	7581.781332	1033.47	<.0001
HEIGHT	1	102.381179	102.381179	13.96	0.0009
DIAMETER*HEIGHT	1	223.842790	223.842790	30.51	<.0001

  

Source	DF	Type III SS	Mean Square	F Value	Pr > F
DIAMETER	1	68.1469958	68.1469958	9.29	0.0051
HEIGHT	1	128.5660997	128.5660997	17.52	0.0003
DIAMETER*HEIGHT	1	223.8427904	223.8427904	30.51	<.0001

  

Parameter	Estimate	Standard Error	t Value	Pr >  t
Intercept	69.39631556	23.83575455	2.91	0.0071
DIAMETER	-5.85584793	1.92133589	-3.05	0.0051
HEIGHT	-1.29708337	0.30984288	-4.19	0.0003
DIAMETER*HEIGHT	0.13465439	0.02437731	5.52	<.0001

## 7.8 Exercises

### Antidotes

This exercise involves a factorial analysis with two categorical variables (these variables could be treated as continuous, but in this example are used as categorical).

**SAS COMMANDS FOR BOX 7.11 Interaction in the antidotes data**

Commands    `proc glm data=gandh.Chapter7;`  
              `class ANTIDOTE DOSE;`  
              `model BLOOD = ANTIDOTE|DOSE / solution;`  
              `run;`

Menu route    Statistics > Anova > Linear Models...

BLOOD → Dependent

ANTIDOTE DOSE → Class

Model

Independent → Effects in Model

ANTIDOTE → Add

DOSE → Add

(ANTIDOTE & DOSE) → Cross

Statistics

Type 1

Parameter estimates

SAS OUTPUT FOR BOX 7.11 **Interaction in the antidotes data**

The GLM Procedure

Dependent Variable: BLOOD

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	3302.869983	471.838569	8.00	0.0003
Error	16	943.679467	58.979967		
Corrected Total	23	4246.549450			

  

	R-Square	Coeff Var	Root MSE	BLOOD Mean
	0.777777	88.29941	7.679842	8.697500

  

Source	DF	Type I SS	Mean Square	F Value	Pr > F
ANTIDOTE	1	1396.900417	1396.900417	23.68	0.0002
DOSE	3	1070.087783	356.695928	6.05	0.0059
ANTIDOTE*DOSE	3	835.881783	278.627261	4.72	0.0152

  

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ANTIDOTE	1	1396.900417	1396.900417	23.68	0.0002
DOSE	3	1070.087783	356.695928	6.05	0.0059
ANTIDOTE*DOSE	3	835.881783	278.627261	4.72	0.0152

  

Parameter	Estimate	Standard Error	t Value	Pr >  t
Intercept	2.05333333 B	4.43395860	0.46	0.6495
ANTIDOTE	31.70333333 B	6.27056439	5.06	0.0001
ANTIDOTE	0.00000000 B	.	.	.
DOSE	-1.92666667 B	6.27056439	-0.31	0.7626
DOSE	-1.55333333 B	6.27056439	-0.25	0.8075
DOSE	-0.46000000 B	6.27056439	-0.07	0.9424
DOSE	0.00000000 B	.	.	.
ANTIDOTE*DOSE 1 5	-30.93333333 B	8.86791721	-3.49	0.0030
ANTIDOTE*DOSE 1 10	-23.54666667 B	8.86791721	-2.66	0.0173
ANTIDOTE*DOSE 1 15	-11.30000000 B	8.86791721	-1.27	0.2208
ANTIDOTE*DOSE 1 20	0.00000000 B	.	.	.
ANTIDOTE*DOSE 2 5	0.00000000 B	.	.	.
ANTIDOTE*DOSE 2 10	0.00000000 B	.	.	.
ANTIDOTE*DOSE 2 15	0.00000000 B	.	.	.
ANTIDOTE*DOSE 2 20	0.00000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

The results could be summarised using the coefficients table to calculate the means for each ANTIDOTE DOSE combination, or the means could be requested directly from SAS using the following commands:

ALTERNATIVE SAS COMMANDS FOR MEANS OF BOX 7.11	
Commands	<pre>proc glm data=gandh.Chapter7;   class ANTIDOTE DOSE;   model BLOOD = ANTIDOTE DOSE;   lsmeans ANTIDOTE*DOSE; run;</pre>
Menu route	Statistics > Anova > Linear Models... BLOOD → Dependent ANTIDOTE DOSE → Class <div style="border: 1px solid black; display: inline-block; padding: 2px;">Model</div> Independent → Effects in Model ANTIDOTE → Add DOSE → Add (ANTIDOTE & DOSE) → Cross <div style="border: 1px solid black; display: inline-block; padding: 2px;">Means</div> with LSmean tab (ANTIDOTE*DOSE) → LSmean

This would give the following output in addition to the ANOVA tables.

ALTERNATIVE SAS COMMANDS FOR MEANS OF BOX 7.11			
The GLM Procedure Least Squares Means			
	ANTIDOTE	DOSE	BLOOD LSMEAN
	1	5	0.8966667
	1	10	8.6566667
	1	15	21.9966667
	1	20	33.7566667
	2	5	0.1266667
	2	10	0.5000000
	2	15	1.5933333
	2	20	2.0533333

### Weight, fat and sex

See SAS output for this exercise in the answers for exercises.