

## 7

## Interactions—getting more complex

### 7.2 Analysis of factorial experiments

The convention used by SPSS to represent interactions is the \* sign, as shown in this first example. Via the menu route, a new kind of operation is required. To select VARIETY and SOWRATE simultaneously for the interaction term, you need to hold down the shift key while clicking on the two variables in the 'Factors & Covariates' pane. We use the convention VARIETY & SOWRATE to indicate when you should do this. Then when the 'Build Terms' arrow is clicked, the interaction term will appear in the 'Model' pane.

SPSS COMMANDS FOR BOX 7.2 A factorial ANOVA of the yield data													
Syntax	<pre>glm YIELD by BLOCK VARIETY SOWRATE       /design BLOCK VARIETY SOWRATE VARIETY*SOWRATE.</pre>												
Menu route	<p>Analyze &gt; General Linear Model &gt; Univariate</p> <p>YIELD → Dependent Variable</p> <p>BLOCK VARIETY SOWRATE → Fixed Factor(s)</p> <div style="border: 1px solid black; padding: 2px; width: fit-content;">Model</div> <p><input checked="" type="radio"/> Custom</p> <p>Factors &amp; Covariates → Build Terms → Model</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;">BLOCK</td> <td style="width: 10%; text-align: center;">→</td> <td style="width: 60%;">BLOCK</td> </tr> <tr> <td>VARIETY</td> <td style="text-align: center;">→</td> <td>VARIETY</td> </tr> <tr> <td>SOWRATE</td> <td style="text-align: center;">→</td> <td>SOWRATE</td> </tr> <tr> <td>VARIETY &amp; SOWRATE</td> <td style="text-align: center;">→</td> <td>VARIETY*SOWRATE</td> </tr> </table>	BLOCK	→	BLOCK	VARIETY	→	VARIETY	SOWRATE	→	SOWRATE	VARIETY & SOWRATE	→	VARIETY*SOWRATE
BLOCK	→	BLOCK											
VARIETY	→	VARIETY											
SOWRATE	→	SOWRATE											
VARIETY & SOWRATE	→	VARIETY*SOWRATE											

Unlike most packages, SPSS has no shorthand way of representing a set of main effects together with all their interactions. There is thus no equivalent of the ']' symbol in the main text. The output is shown below:

SPSS OUTPUT FOR BOX 7.2 **A factorial ANOVA of the yield data****General linear model****Between-Subjects Factors**

		N
BLOCK	1	8
	2	8
	3	8
VARIETY	1	12
	2	12
SOWRATE	1	6
	2	6
	3	6
	4	6

**Tests of Between-Subjects Effects**

Dependent Variable: YIELD

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.471 <sup>a</sup>	9	.941	2.483	.062
Intercept	1748.873	1	1748.873	4613.664	.000
BLOCK	.394	2	.197	.519	.606
VARIETY	2.147	1	2.147	5.665	.032
SOWRATE	5.874	3	1.958	5.165	.013
VARIETY * SOWRATE	5.660E-02	3	1.887E-02	.050	.985
Error	5.307	14	.379		
Total	1762.651	24			
Corrected Total	13.778	23			

a. R Squared = .615 (Adjusted R Squared = .367)

**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:

SPSS COMMANDS FOR BOX 7.3 <b>The coefficients table from the factorial analysis of Box 7.2</b>	
Syntax	<pre>glm YIELD by BLOCK VARIETY SOWRATE   /print parameters   /design BLOCK VARIETY SOWRATE VARIETY*SOWRATE.</pre>
Menu route	<p>Analyze &gt; General Linear Model &gt; Univariate</p> <p>YIELD → Dependent Variable</p> <p>BLOCK VARIETY SOWRATE → Fixed Factor(s)</p> <p><input type="text" value="Model"/></p> <p><input type="radio"/> Custom</p> <p>Factors &amp; Covariates → Build Terms → Model</p> <p>BLOCK → BLOCK</p> <p>VARIETY → VARIETY</p> <p>SOWRATE → SOWRATE</p> <p>VARIETY &amp; SOWRATE → VARIETY*SOWRATE</p> <p><input type="text" value="Options"/></p> <p><input checked="" type="checkbox"/> Parameter estimates</p>

In addition to the ANOVA table, this will give you the coefficient table. SPSS 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.

**SPSS OUTPUT FOR BOX 7.3 The coefficients table from the factorial analysis of Box 7.2**

**Parameter Estimates**

Dependent Variable: YIELD

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	9.002	.397	22.652	.000	8.150	9.855
[BLOCK=1]	1.150E-02	.308	.037	.971	-.649	.672
[BLOCK=2]	.277	.308	.901	.383	-.383	.938
[BLOCK=3]	0 <sup>a</sup>	.	.	.	.	.
[VARIETY=1]	.537	.503	1.068	.304	-.542	1.615
[VARIETY=2]	0 <sup>a</sup>	.	.	.	.	.
[SOWRATE=1]	-1.186	.503	-2.359	.033	-2.264	-.108
[SOWRATE=2]	-1.358	.503	-2.702	.017	-2.437	-.280
[SOWRATE=3]	-.901	.503	-1.793	.095	-1.980	.177
[SOWRATE=4]	0 <sup>a</sup>	.	.	.	.	.
[VARIETY=1] * [SOWRATE=1]	.150	.711	.211	.836	-1.375	1.675
[VARIETY=1] * [SOWRATE=2]	.162	.711	.227	.823	-1.363	1.686
[VARIETY=1] * [SOWRATE=3]	-6.53E-02	.711	-.092	.928	-1.590	1.459
[VARIETY=1] * [SOWRATE=4]	0 <sup>a</sup>	.	.	.	.	.
[VARIETY=2] * [SOWRATE=1]	0 <sup>a</sup>	.	.	.	.	.
[VARIETY=2] * [SOWRATE=2]	0 <sup>a</sup>	.	.	.	.	.
[VARIETY=2] * [SOWRATE=3]	0 <sup>a</sup>	.	.	.	.	.
[VARIETY=2] * [SOWRATE=4]	0 <sup>a</sup>	.	.	.	.	.

a. This parameter is set to zero because it is redundant

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
9.002	1      0.0115	1      0.537	1      -1.186	1 1    0.1500
	2      0.277	2      0	2      -1.358	1 2    0.162
	3      0		3      -0.901	1 3    -0.0653
			4      0	1 4    0
				2 1    0
				2 2    0
				2 3    0
				2 4    0
	Av    0.0962	0.2685	-0.8613	

It is a little complicated to calculate the adjusted mean for a level of a main effect when the model contains interactions. We first follow the same steps as we did when there were no interactions: namely, we sum the intercept and the average coefficients for the other variables. For example, for sowrate 4 this is:  $9.002 + 0.0962 + 0.2685 = 9.3667$ . 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 9.3667 (as in Box 7.4 of the main text). SPSS 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 SPSS 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	9.002	0.0962	0.2685	-1.186	0.075	8.2557
	2	9.002	0.0962	0.2685	-1.358	0.081	8.0897
	3	9.002	0.0962	0.2685	-0.901	-0.03265	8.4331
	4	9.002	0.0962	0.2685	0	0	9.3667
Variety	1	9.002	0.0962	0.537	-0.8613	0.0617	8.8356
	2	9.002	0.0962	0	-0.8613	0	8.2369

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.

SPSS COMMANDS FOR BOX 7.4 <b>Obtaining the means for the main effects only</b>	
Syntax	<pre>glm YIELD by BLOCK VARIETY SOWRATE       /emmeans table(VARIETY)       /emmeans table(SOWRATE)       /design BLOCK VARIETY SOWRATE VARIETY*SOWRATE.</pre>
Menu route	<p>Analyze &gt; General Linear Model &gt; Univariate</p> <p>YIELD → Dependent Variable</p> <p>BLOCK VARIETY SOWRATE → Fixed Factor(s)</p> <p><b>Model</b></p> <p><input checked="" type="radio"/> Custom</p> <p>Factors &amp; Covariates → Build Terms → Model</p> <p>BLOCK → BLOCK</p> <p>VARIETY → VARIETY</p> <p>SOWRATE → SOWRATE</p> <p>VARIETY &amp; SOWRATE → VARIETY*SOWRATE</p> <p><b>Options</b></p> <p>VARIETY SOWRATE → Display Means for</p>

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

SPSS OUTPUT FOR BOX 7.4 **Summarising the results when the interaction is not significant**

**Estimated marginal means**

**1. VARIETY**

Dependent Variable: YIELD

VARIETY	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	8.836	.178	8.454	9.217
2	8.237	.178	7.856	8.618

**2. SOWRATE**

Dependent Variable: YIELD

SOWRATE	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	8.256	.251	7.717	8.795
2	8.090	.251	7.550	8.629
3	8.433	.251	7.894	8.972
4	9.367	.251	8.828	9.906

**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:

**SPSS COMMANDS FOR BOX 7.5 Analysing a factorial experiment with a significant interaction**

Syntax            `glm BLOOMS by BED WATER SHADE`  
                       `/print parameters`  
                       `/design BED WATER SHADE WATER*SHADE.`

Menu route        Analyze > General Linear Model > Univariate  
                       BLOOMS → Dependent Variable  
                       BED WATER SHADE → Fixed Factor(s)

Model

Custom

Factors & Covariates → Build Terms → Model

BED	→	BED
WATER	→	WATER
SHADE	→	SHADE
WATER & SHADE	→	WATER*SHADE

Options

Parameter estimates

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

**General linear model**

**Between-Subjects Factors**

		N
BED	1	9
	2	9
	3	9
WATER	1	9
	2	9
	3	9
SHADE	1	9
	2	9
	3	9

(Contd.)

## SPSS OUTPUT FOR BOX 7.5 (Contd.)

**Tests of Between-Subjects Effects**

Dependent Variable: BLOOMS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	194871.213 <sup>a</sup>	10	19487.121	10.949	.000
Intercept	449263.141	1	449263.141	252.423	.000
BED	13811.350	2	6905.675	3.880	.042
WATER	103625.787	2	51812.893	29.112	.000
SHADE	36375.937	2	18187.968	10.219	.001
WATER * SHADE	41058.139	4	10264.535	5.767	.005
Error	28476.835	16	1779.802		
Total	672611.190	27			
Corrected Total	223348.048	26			

a. R Squared = .873 (Adjusted R Squared = .793)

**Parameter Estimates**

Dependent Variable: BLOOMS

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	153.105	26.928	5.686	.000	96.021	210.189
[BED=1]	-50.152	19.887	-2.522	.023	-92.312	-7.993
[BED=2]	-4.693	19.887	-.236	.816	-46.853	37.466
[BED=3]	0 <sup>a</sup>	.	.	.	.	.
[WATER=1]	-55.603	34.446	-1.614	.126	-128.626	17.419
[WATER=2]	-57.193	34.446	-1.660	.116	-130.216	15.829
[WATER=3]	0 <sup>a</sup>	.	.	.	.	.
[SHADE=1]	162.227	34.446	4.710	.000	89.204	235.249
[SHADE=2]	41.920	34.446	1.217	.241	-31.103	114.943
[SHADE=3]	0 <sup>a</sup>	.	.	.	.	.
[WATER=1] * [SHADE=1]	-211.407	48.714	-4.340	.001	-314.676	-108.137
[WATER=1] * [SHADE=2]	-76.593	48.714	-1.572	.135	-179.863	26.676
[WATER=1] * [SHADE=3]	0 <sup>a</sup>	.	.	.	.	.
[WATER=2] * [SHADE=1]	-25.657	48.714	-.527	.606	-128.926	77.613
[WATER=2] * [SHADE=2]	-12.860	48.714	-.264	.795	-116.129	90.409
[WATER=2] * [SHADE=3]	0 <sup>a</sup>	.	.	.	.	.
[WATER=3] * [SHADE=1]	0 <sup>a</sup>	.	.	.	.	.
[WATER=3] * [SHADE=2]	0 <sup>a</sup>	.	.	.	.	.
[WATER=3] * [SHADE=3]	0 <sup>a</sup>	.	.	.	.	.

a. This parameter is set to zero because it is redundant

100 Interactions—getting more complex

The means for all combinations of WATER and SHADE can be calculated from the parameter estimates 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 SPSS OUTPUT WITH BOX 7.6						
WATER/ SHADE Level	Intercept	BED (average coefficient)	WATER (relevant coefficient)	SHADE (relevant coefficient)	Interaction (relevant coefficient)	Total
1 1	153.105	-18.2817	-55.603	162.227	-211.407	30.04
1 2	153.105	-18.2817	-55.603	41.920	-76.593	44.55
1 3	153.105	-18.2817	-55.603	0	0	79.22
2 1	153.105	-18.2817	-57.193	162.227	-25.657	214.20
2 2	153.105	-18.2817	-57.193	41.920	-12.860	106.69
2 3	153.105	-18.2817	-57.193	0	0	77.63
3 1	153.105	-18.2817	0	162.227	0	297.05
3 2	153.105	-18.2817	0	41.920	0	176.74
3 3	153.105	-18.2817	0	0	0	134.82

To obtain these means directly, use the following commands:

SPSS COMMANDS FOR BOX 7.6 <b>Summarising the results with a significant interaction</b>	
Syntax	<pre>glm BLOOMS by BED WATER SHADE   /emmeans table(WATER*SHADE)   /design BED WATER SHADE WATER*SHADE.</pre>
Menu route	<p>Analyze &gt; General Linear Model &gt; Univariate</p> <p>BLOOMS → Dependent Variable</p> <p>BED WATER SHADE → Fixed Factor(s)</p> <p><b>Model</b></p> <p><input checked="" type="radio"/> Custom</p> <p>Factors &amp; Covariates → Build Terms → Model</p> <p>BED → BED</p> <p>WATER → WATER</p> <p>SHADE → SHADE</p> <p>WATER &amp; SHADE → WATER*SHADE</p> <p><b>Options</b></p> <p>WATER*SHADE → Display Means for</p>

In addition to the ANOVA table this will produce the following table of means:

SPSS OUTPUT FOR BOX 7.6 <b>Summarising the results with a significant interaction</b>					
<b>Estimated marginal means</b>					
<b>WATER * SHADE</b>					
Dependent Variable: BLOOMS					
WATER	SHADE	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	1	30.040	24.357	-21.595	81.675
	2	44.547	24.357	-7.088	96.181
	3	79.220	24.357	27.585	130.855
2	1	214.200	24.357	162.565	265.835
	2	106.690	24.357	55.055	158.325
	3	77.630	24.357	25.995	129.265
3	1	297.050	24.357	245.415	348.685
	2	176.743	24.357	125.109	228.378
	3	134.823	24.357	83.189	186.458

## 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.

SPSS COMMANDS FOR BOX 7.7										
<b>Analysing interactions with categorical and continuous variables: the leprosy dataset</b>										
Syntax	<pre>glm BACAFTER by TREATMT with BACBEF       /print parameters       /design TREATMT BACBEF TREATMT*BACBEF.</pre>									
Menu route	<p>Analyze &gt; General Linear Model &gt; Univariate</p> <p>BACAFTER → Dependent Variable</p> <p>TREATMT → Fixed Factor(s)</p> <p>BACBEF → Covariate(s)</p> <p><input type="text" value="Model"/></p> <p><input type="radio"/> Custom</p> <p>Factors &amp; Covariates → Build Terms → Model</p> <table> <tr> <td>TREATMT</td> <td>→</td> <td>TREATMT</td> </tr> <tr> <td>BACBEF</td> <td>→</td> <td>BACBEF</td> </tr> <tr> <td>TREATMT &amp; BACBEF</td> <td>→</td> <td>TREATMT*BACBEF</td> </tr> </table> <p><input type="text" value="Options"/></p> <p><input checked="" type="checkbox"/> Parameter estimates</p>	TREATMT	→	TREATMT	BACBEF	→	BACBEF	TREATMT & BACBEF	→	TREATMT*BACBEF
TREATMT	→	TREATMT								
BACBEF	→	BACBEF								
TREATMT & BACBEF	→	TREATMT*BACBEF								

SPSS OUTPUT FOR BOX 7.7

**Analysing interactions with categorical and continuous variables: the leprosy dataset**

**General linear model**

**Between-Subjects Factors**

	N
TREATMT 1	10
2	10
3	10

**Tests of Between-Subjects Effects**

Dependent Variable: BACAFTER

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	672.077 <sup>a</sup>	5	134.415	8.514	.000
Intercept	6.554E-02	1	6.554E-02	.004	.949
TREATMT	5.827	2	2.913	.185	.833
BACBEF	482.630	1	482.630	30.570	.000
TREATMT * BACBEF	1.250	2	.625	.040	.961
Error	378.902	24	15.788		
Total	3975.441	30			
Corrected Total	1050.979	29			

a. R Squared = .639 (Adjusted R Squared = .564)

**Parameter Estimates**

Dependent Variable: BACAFTER

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	1.716	4.046	.424	.675	-6.633	10.066
[TREATMT=1]	-2.789	4.895	-.570	.574	-12.891	7.314
[TREATMT=2]	-2.739	5.176	-.529	.602	-13.422	7.945
[TREATMT=3]	0 <sup>a</sup>	.	.	.	.	.
BACBEF	.934	.333	2.808	.010	.247	1.620
[TREATMT=1] * BACBEF	-.106	.418	-.252	.803	-.968	.757
[TREATMT=2] * BACBEF	-2.78E-02	.411	-.068	.947	-.876	.820
[TREATMT=3] * BACBEF	0 <sup>a</sup>	.	.	.	.	.

a. This parameter is set to zero because it is redundant

104 Interactions—getting more complex

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

USING THE SPSS COEFFICIENTS TO PRODUCE THE FITTED VALUE EQUATIONS OF TABLE 7.3					
	Intercept	TREATMT	BACBEF	Interaction	Fitted Line: BACAFTER=
TREATMT 1	1.716	-2.789	0.934	-0.106	-1.073 + 0.828*BACBEF
TREATMT 2	1.716	-2.739	0.934	-0.0278	-1.023 + 0.906*BACBEF
TREATMT 3	1.716	0	0.934	0	1.716 + 0.934*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, SPSS will adjust them for the mean value of BACBEF (for details see main text).

SPSS COMMANDS FOR BOX 7.8	
<b>Obtaining adjusted means to compare treatments, when the model contains a covariate</b>	
Syntax	<pre>glm BACAFTER by TREATMT with BACBEF     /emmeans table(TREATMT)     /design TREATMT BACBEF TREATMT*BACBEF.</pre>
Menu route	<p>Analyze &gt; General Linear Model &gt; Univariate</p> <p>BACAFTER → Dependent Variable</p> <p>TREATMT → Fixed Factor(s)</p> <p>BACBEF → Covariate(s)</p> <p><b>Model</b></p> <p><input checked="" type="radio"/> Custom</p> <p>Factors &amp; Covariates → Build Terms → Model</p> <p>TREATMT → TREATMT</p> <p>BACBEF → BACBEF</p> <p>TREATMT &amp; BACBEF → TREATMT*BACBEF</p> <p><b>Options</b></p> <p>TREATMT → Display Means for</p>

In addition to the ANOVA table, this will produce the following table of means:

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

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**Estimated marginal means**

**TREATMT**

Dependent Variable: BACAFTER

TREATMT	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	8.201 <sup>a</sup>	1.313	5.491	10.911
2	9.121 <sup>a</sup>	1.286	6.467	11.776
3	12.171 <sup>a</sup>	1.262	9.565	14.776

a. Evaluated at covariates appeared in the model: BACBEF = 11.19490

By requesting the means for treatment, it is noted by SPSS that a covariate is involved, so the treatment means are automatically adjusted, and the mean value of the covariate, which was used in the adjustment, is also given.

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.

SPSS COMMANDS FOR BOX 7.10 <b>Testing for interactions between two continuous variables</b>	
Syntax	<pre>glm VOLUME with DIAMETER HEIGHT   /print parameters   /design DIAMETER HEIGHT DIAMETER*HEIGHT.</pre>
Menu route	<p>Analyze &gt; General Linear Model &gt; Univariate</p> <p>VOLUME → Dependent Variable</p> <p>HEIGHT DIAMETER → Covariate(s)</p> <p><input type="text" value="Model"/></p> <p><input type="radio"/> Custom</p> <p>Factors &amp; Covariates → Build Terms → Model</p> <p>DIAMETER → DIAMETER</p> <p>HEIGHT → HEIGHT</p> <p>DIAMETER &amp; HEIGHT → DIAMETER*HEIGHT</p> <p><input type="text" value="Options"/></p> <p><input checked="" type="checkbox"/> Parameter estimates</p>

SPSS OUTPUT FOR BOX 7.10 **Testing for interactions between two continuous variables****General linear model****Tests of Between-Subjects Effects**

Dependent Variable: VOLUME

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7908.005 <sup>a</sup>	3	2636.002	359.312	.000
Intercept	62.185	1	62.185	8.476	.007
DIAMETER	68.147	1	68.147	9.289	.005
HEIGHT	128.566	1	128.566	17.525	.000
DIAMETER * HEIGHT	223.843	1	223.843	30.512	.000
Error	198.079	27	7.336		
Total	36324.990	31			
Corrected Total	8106.084	30			

a. R Squared = .976 (Adjusted R Squared = .973)

**Parameter Estimates**

Dependent Variable: VOLUME

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	69.396	23.836	2.911	.007	20.489	118.303
DIAMETER	-5.856	1.921	-3.048	.005	-9.798	-1.914
HEIGHT	-1.297	.310	-4.186	.000	-1.933	-.661
DIAMETER * HEIGHT	.135	.024	5.524	.000	8.464E-02	.185

**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).



### Tests of Between-Subjects Effects

Dependent Variable: BLOOD

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3302.870 <sup>a</sup>	7	471.839	8.000	.000
Intercept	1815.516	1	1815.516	30.782	.000
ANTIDOTE	1396.900	1	1396.900	23.684	.000
DOSE	1070.088	3	356.696	6.048	.006
ANTIDOTE * DOSE	835.882	3	278.627	4.724	.015
Error	943.679	16	58.980		
Total	6062.066	24			
Corrected Total	4246.549	23			

a. R Squared = .778 (Adjusted R Squared = .681)

### Parameter Estimates

Dependent Variable: BLOOD

Parameter	B	Std.	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	2.053	4.434	.463	.650	-7.346	11.453
[ANTIDOTE=1]	31.703	6.271	5.056	.000	18.410	44.996
[ANTIDOTE=2]	0 <sup>a</sup>	.	.	.	.	.
[DOSE=5]	-1.927	6.271	-.307	.763	-15.220	11.366
[DOSE=10]	-1.553	6.271	-.248	.808	-14.846	11.740
[DOSE=15]	-.460	6.271	-.073	.942	-13.753	12.833
[DOSE=20]	0 <sup>a</sup>	.	.	.	.	.
[ANTIDOTE=1] * [DOSE=5]	-30.933	8.868	-3.488	.003	-49.732	-12.134
[ANTIDOTE=1] * [DOSE=10]	-23.547	8.868	-2.655	.017	-42.346	-4.748
[ANTIDOTE=1] * [DOSE=15]	-11.300	8.868	-1.274	.221	-30.099	7.499
[ANTIDOTE=1] * [DOSE=20]	0 <sup>a</sup>	.	.	.	.	.
[ANTIDOTE=2] * [DOSE=5]	0 <sup>a</sup>	.	.	.	.	.
[ANTIDOTE=2] * [DOSE=10]	0 <sup>a</sup>	.	.	.	.	.
[ANTIDOTE=2] * [DOSE=15]	0 <sup>a</sup>	.	.	.	.	.
[ANTIDOTE=2] * [DOSE=20]	0 <sup>a</sup>	.	.	.	.	.

a. This parameter is set to zero because it is redundant

110 Interactions—getting more complex

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 SPSS using the following commands:

ALTERNATIVE SPSS COMMANDS FOR MEANS OF BOX 7.11	
Syntax	<pre>glm BLOOD by ANTIDOTE DOSE       /emmeans table(ANTIDOTE*DOSE)       /design ANTIDOTE DOSE ANTIDOTE*DOSE.</pre>
Menu route	Analyze > General Linear Model > Univariate BLOOD → Dependent Variable ANTIDOTE DOSE → Fixed Factor(s) <input type="text" value="Model"/> <input checked="" type="radio"/> Custom Factors & Covariates → Build Terms → Model ANTIDOTE → ANTIDOTE DOSE → DOSE ANTIDOTE & DOSE → ANTIDOTE*DOSE <input type="text" value="Options"/> ANTIDOTE*DOSE → Display Means for

This will produce the following table of means in addition to the ANOVA table:

SPSS OUTPUT GIVING MEANS OF BOX 7.11					
<b>Estimated marginal means</b>					
<b>ANTIDOTE * DOSE</b>					
Dependent Variable: BLOOD					
ANTIDOTE	DOSE	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	5	.897	4.434	-8.503	10.296
	10	8.657	4.434	-.743	18.056
	15	21.997	4.434	12.597	31.396
	20	33.757	4.434	24.357	43.156
2	5	.127	4.434	-9.273	9.526
	10	.500	4.434	-8.900	9.900
	15	1.593	4.434	-7.806	10.993
	20	2.053	4.434	-7.346	11.453

**Weight, fat and sex**

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