

Main Effects and Interactions

So far, we've talked about studies in which there is just one independent variable, such as "violence of television program." You might randomly assign people to watch television programs with either lots of violence or no violence and then compare them in some way, such as their attitudes toward the death penalty. We've also talked about studies that have more than just two levels of the independent variable. Using the example above, we could add a level in which people watched television programs with a moderate amount of violence. Even though there are three levels, there is still just one independent variable: TV violence. This chapter is designed to introduce you to studies where there is more than one independent variable. For example, you might be curious about whether the effect of TV violence is different for men and women. In this case, you would want to conduct a study with two independent variables: TV violence and gender.

Factorial Design

A study that has more than one independent variable is said to use a **factorial design**. A "factor" is another name for an independent variable. Factorial designs are described using "A x B" notation, in which "A" stands for the number of levels of one independent variable and "B" stands for the number of levels of the second independent variable. For example, if you are using two levels of TV violence (high vs. none) and two levels of gender (male vs. female), then you are using a 2 x 2 factorial design. If you add a medium level of TV violence to your design, then you have a 3 x 2 factorial design. In your methods section, you would write, "This study is a 3 (television violence: high, medium, or none) by 2 (gender: male or female) factorial design." A 2 x 2 x 2 factorial design is a design with three independent variables, each with two levels.

Main Effects

A "main effect" is the effect of one of your independent variables on the dependent variable, ignoring the effects of all other independent variables. To examine main effects, let's look at a study in which 7-year-olds and 15-year-olds are given IQ tests, and then two weeks later, their teachers are told that some small number of students in their class are "on the verge of an intellectual growth spurt." These students will be selected completely at random, without regard to their actual test scores, to see if teacher expectations alone have an impact on student performance. We include age as another factor to see if teacher expectations have a different effect depending on the age of the student. This would be a 2 (teacher expectations: high or normal) x 2 (age of student: 7 years or 15 years) factorial design. Six months after the teachers are given high expectations for some students, all the students are given another IQ test. The mean IQ test scores for the four possible conditions of this study, which I have made up, are given in Table 1.

Table 1

Mean IQ Test Scores by Teacher Expectation and Age of Student

Teacher expectations	Age of student	
	7 years	15 years
high	115	110
normal	100	110

Because a main effect is the effect of one independent variable on the dependent variable, ignoring the effects of other independent variables, you will have a total of two potential main effects in this study: one for age of student and one for teacher expectations. **In general, there is one main effect for every independent variable in a study.** To look for a main effect of teacher expectations, you would calculate the average IQ score *across both 7-year-olds and 15-year-olds*. This is done in Table 2.

Table 2

Main Effect of Teacher Expectations

Teacher expectations	Age of student		Average
	7 years	15 years	
high	115	110	112.5
normal	100	110	105

Note that these averages assume that there are an equal number of people in the 7-year-old and the 15-year-old conditions¹. Looking at these two averages, we see that they differ by 7.5 IQ points. Students whose teachers had high expectations scored, on average, 7.5 points higher than students whose teachers had normal expectations. To determine whether the “main effect of teacher expectation on IQ score” is significant, you would need to test whether the difference of 7.5 IQ points is greater than you would expect by chance. To do this, you need a statistical test. Before we get to that test, however, we should look at the main effect of student age.

Table 3

Main Effect of Age of Student

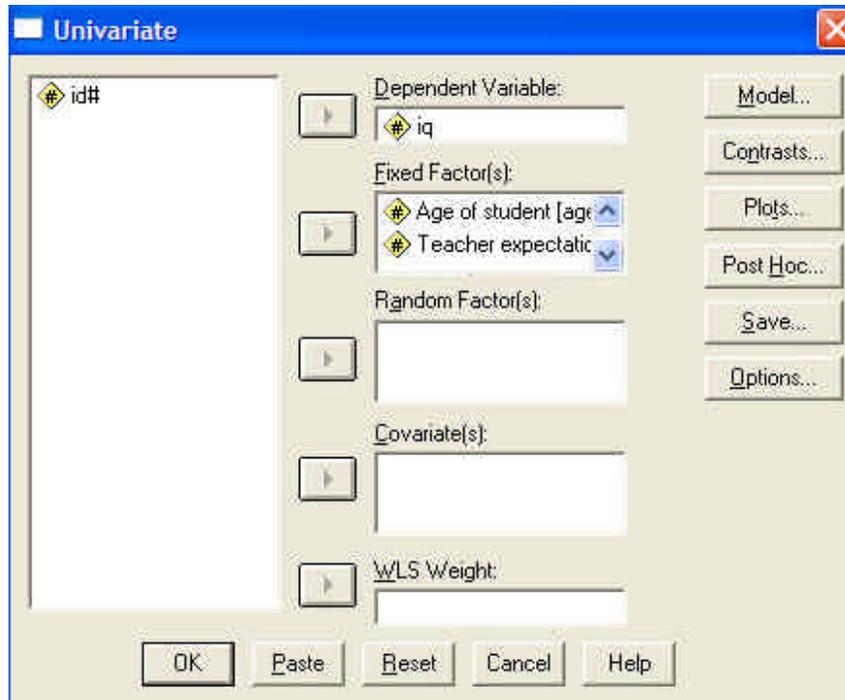
Teacher expectations	Age of student	
	7 years	15 years
high	115	110
normal	100	110
Average	107.5	110

In Table 3, we see that IQ scores of 7-year-olds and 15-year-olds differ by 2.5 points, on average, with 15-year-olds doing slightly better. To determine whether there is a main effect of student age, you would need to test whether the 2.5-point difference is greater than you would expect by chance.

¹ If there were unequal numbers, you would need to compute a weighted average in which you multiplied each mean by the number of scores that contributed to the mean, added those two weighted means together, and then divided by the total number of scores. In our case, we'll assume an equal number of people in each of the four cells that make up Table 1.

Detecting main effects in SPSS output. To analyze a factorial design in SPSS, you would select Analyze → General Linear Model → Univariate. You would then get the screen shown in Figure 1.

Figure 1. Setting up the analysis of the effects of teacher expectations and student age on IQ score.



As you can see in Figure 1, the dependent variable is IQ score and the two independent variables are placed into the “Fixed Factors” window. Running the above analysis produces the output shown in Figure 2.

Figure 2. SPSS output from analysis of effect of teacher expectation and student age on IQ.

Tests of Between-Subjects Effects

Dependent Variable: IQ

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1187.500 ^a	3	395.833	7.125	.001
Intercept	473062.500	1	473062.500	8515.125	.000
AGE	62.500	1	62.500	1.125	.296
EXPECT	562.500	1	562.500	10.125	.003
AGE * EXPECT	562.500	1	562.500	10.125	.003
Error	2000.000	36	55.556		
Total	476250.000	40			
Corrected Total	3187.500	39			

a. R Squared = .373 (Adjusted R Squared = .320)

For now, the part of the output you need to be concerned about is the part with the box around it in Figure 2. This describes the tests for the main effects of student age and teacher expectations. Looking under the “Sig.” column, we see that the main effect of student age is not significant ($p = .296$), but the main effect of teacher expectations is significant ($p = .003$). **If any main effect is significant, you must also report the pattern of means for that main effect.** In this case, we know the means of each level of teacher expectations from Table 2. In reporting the results of the output in Figure 2, you need to list four pieces of information: the degrees of freedom for the main effect, the degrees of freedom for error, the F value, and the p value. Here’s how it might look in APA style:

The main effect of student age on IQ was not significant ($F(1,36) = 1.125, p = .296$) but the main effect of teacher expectation on IQ was significant such that students whose teachers had high expectations received higher scores than students whose teachers had normal expectations, ($F(1,36) = 10.125, p = .003$).

Two things to keep in mind when writing these out: 1) All the statistical letters (F and p) are italicized; and 2) The phrasing is of the format: “The main effect of the IV on the DV.” You can also describe the results in terms of the levels of the independent variable:

The high-expectation group scored significantly higher than the low-expectation group ($F(1,36) = 10.125, p = .003$), while the scores of 7-year-olds and 15-year-olds were not significantly different ($F(1,36) = 1.125, p = .296$).

That approach has the advantage of being more concise.

Interactions

A statistical interaction occurs when the effect of one independent variable on the dependent variable *changes* depending on the level of another independent variable. In our current design, this is equivalent to asking whether the effect of teacher expectations changes depending on the age of student. If the effect of teacher expectations on IQ for 15-year-olds is different from the effect of teacher expectations on IQ for 7-year-olds, then there is an interaction. To determine if this is the case, we need to look at the **simple main effects**: the main effect of one independent variable (e.g., teacher expectation) at each level of another independent variable (for 7-year-olds and for 15-year-olds). This is shown in Table 4.

Table 4.

Simple Main Effects

Teacher expectations	Age of student	
	7 years	15 years
high	115	110
normal	100	110
Difference	15	0

The simple main effect of teacher expectation for 7-year-olds is 15 points, whereas the simple main effect of teacher expectation for 15-year-olds is 0 points. The effect of teacher expectation is *changing* depending on the age of the student. To know if the difference between 15 and 0 is significant (so large that it is unlikely to have occurred by chance), we need to conduct a statistical test. This information is provided in the output in Figure 2 in the row labeled “AGE *

EXPECT". Under the "Sig." column is the p -value for the interaction: $p = .003$. To communicate these results, you would write,

There was a significant interaction between student age and teacher expectations, $F(1,36) = 10.125, p = .003$.²

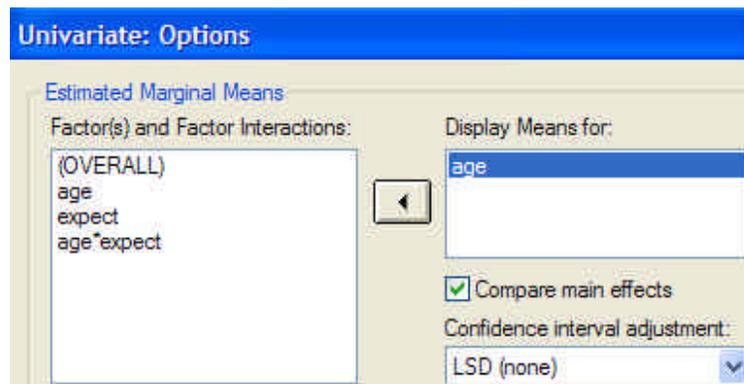
Note that an interaction is phrased with both independent variables ("between student age and teacher expectations") and no dependent variable. Just as with main effects, you must describe the pattern of means that contributes to a significant interaction. **The easiest way to communicate an interaction is to discuss it in terms of the simple main effects.** Describe one simple main effect, then describe the other in such a way that it is clear how the two are different. For example, you could say:

For seven-year-olds, high teacher expectations led to higher IQ scores than normal teacher expectations. For fifteen-year-olds, teacher expectations had no effect.

It may take several attempts for you to phrase your description of an interaction in a way that makes it clear to the reader. Do not expect your first attempt to be the best.

Testing simple main effects. In the description of the interaction above, we wrote that for seven-year-olds, high teacher expectations led to higher IQ scores than normal teacher expectations. This is a simple main effect of teacher expectations on IQ scores for seven-year-olds. To find out if this simple main effect is significant ($p < .05$), you will need to do some minor programming because SPSS doesn't allow you to test simple main effects directly. Return to the dialog box in Figure 1 and press "Options." This will open a new box, shown in Figure 3.

Figure 3. Options dialog box for univariate ANOVA.



Select one of the independent variables and move it into the "Display Means for" box, then click on "Compare main effects." In the "Confidence interval adjustment" drop-down box, select "Bonferroni." Last step: Instead of actually running this analysis by pressing OK, press PASTE (the button to the right of OK).

A new window will open that contains the "syntax" (programming code) for SPSS to run the analysis you have selected:

² Note: The only reason the interaction F and p are the same as for the main effect of expectations is that I made these data up. Usually, the interaction F and p are different from the F and p for main effects.

```

UNIANOVA
  iq BY age expect
  /METHOD = SSTYPE(3)
  /INTERCEPT = INCLUDE
  /EMMEANS = TABLES(age) COMPARE ADJ(LSD)
  /CRITERIA = ALPHA(.05)
  /DESIGN = age expect age*expect .

```

You need to modify this syntax to give you simple main effects. The line you will modify begins with "/EMMEANS" (estimated marginal means). Change this line to:

```

/EMMEANS = TABLES(age*expect) COMPARE(expect) ADJ(BONFERRONI)

```

To run this program from the syntax window, select Run -> All.

This will produce two new output windows: 1) a table of means showing age by teacher expectations (this was produced by the TABLES command) and 2) the simple main effects: a comparison of the effect of teacher expectations at different levels of student age (produced by the COMPARE command), shown in Figure 4.

Figure 4. SPSS output from a test for simple main effects

Pairwise Comparisons

Dependent Variable: iq

Age of student	(I) Teacher expectation	(J) Teacher expectation	Mean Difference (I-J)	Std. Error	Sig. ^a
7	Normal	High	-15.000*	3.333	.000
	High	Normal	15.000*	3.333	.000
15	Normal	High	4.16E-016	3.333	1.000
	High	Normal	-4.16E-016	3.333	1.000

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

In the first column is the Student Age independent variable. The two rows at the top show the effect of expectations for 7-year-olds. We see in the first row that the mean difference between normal and high expectation children is -15. Because this number is negative, the high expectation group must have scored higher than the normal expectation group. Following this row to the right, we see that the effect of expectations for 7-year-olds is significant ($p < .001$). In the second row is just a repeat of the first row, but in reverse, so you can ignore it. In the third row, we see the effect of expectations for 15-year-olds. The mean difference is close to zero and it is not significant ($p = 1.0$).

The last box of output (Figure 5) gives you the test statistics you need to document the simple main effects:

Figure 5. SPSS output showing F and df for simple main effects.

Univariate Tests

Dependent Variable: iq

Age of student		Sum of Squares	df	Mean Square	F	Sig.
7	Contrast	1125.000	1	1125.000	20.250	.000
	Error	2000.000	36	55.556		
15	Contrast	8.67E-031	1	8.67E-031	.000	1.000
	Error	2000.000	36	55.556		

Each F tests the simple effects of Teacher expectation within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Looking in the far-right column, we see the same p -values that were in the previous table: .000 and 1.000, but now you have the F -value and degrees of freedom to back up those p -values. You could now expand your previous summary of the simple main effects by adding the results of the statistical tests:

For seven-year-olds, high teacher expectations led to higher IQ scores than normal teacher expectations ($F(1,36) = 20.25, p < .001$). For fifteen-year-olds, teacher expectations had no effect ($F(1,36) = .000, p = 1$).

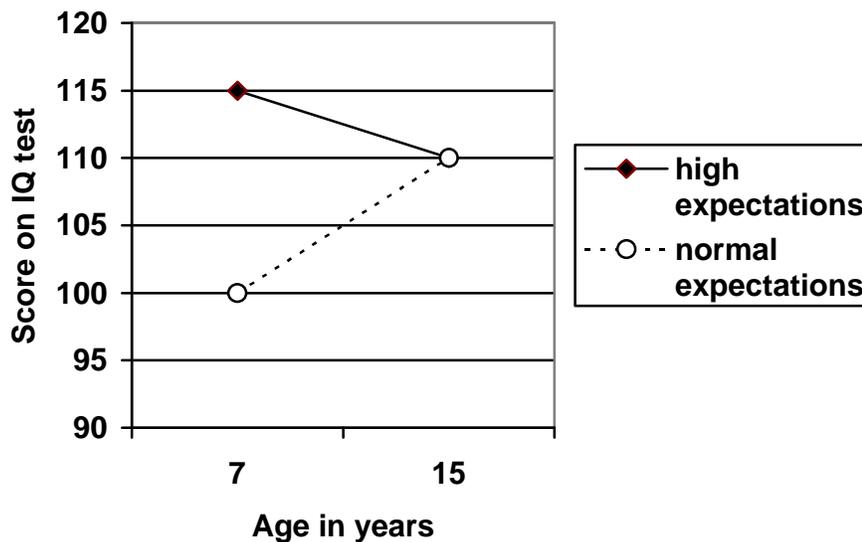
Interpreting Main Effects and Interactions through Figures

You can often get a quick idea of the pattern of results from a study by looking at a figure. It's important to remember that figures cannot tell you whether a pattern is significant – for that, you need the results of a statistical test.

Line graphs

Figure 7 provides a graphical representation of the mean IQ scores of the high- and normal-expectation 7-year-old and 15-year-old students. The dependent variable always goes on the y-axis and the two independent variables go along the x-axis and in the legend. Be sure to always label your x and y axes.

Figure 7. Effects of age and teacher expectations on IQ scores.

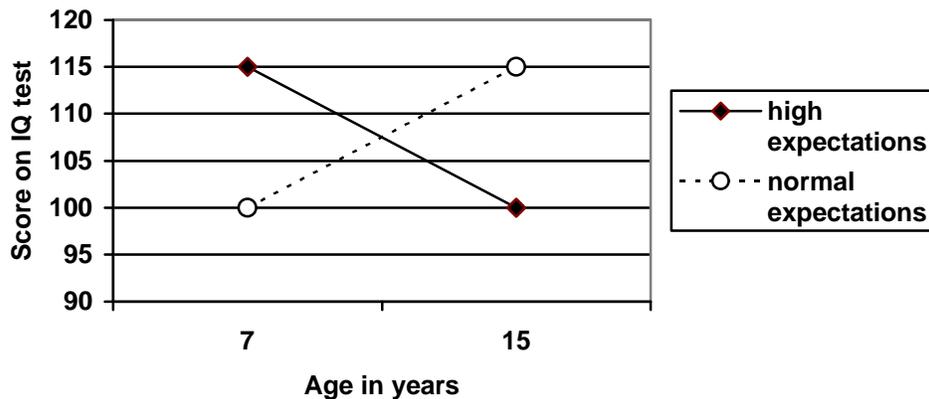


Interactions. The less parallel the lines are, the more likely there is to be a significant interaction. In Figure 7, we see that the lines are definitely *not* parallel, so we would expect an interaction.

Main effects. For the main effect of expectations, look to see whether the two black diamonds are, in general, higher or lower than the two open circles in Figure 7. For 15-year-olds, the black diamond and open circle have the same value, but the black diamond is much higher than the open circle for 7-year-olds. Averaging across 7-year-olds and 15-year-olds, we would say that the black diamonds are generally higher than the open circles. Thus, we would expect a main effect of expectations such that high expectations lead to higher scores than low expectations.

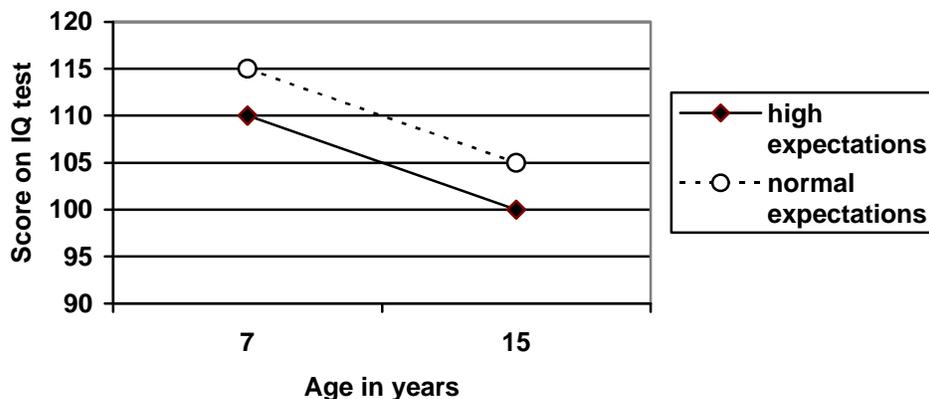
For the main effect of age, look to see whether the average of the diamond and circle in the 7-year-old condition is higher or lower than the average of the diamond and circle in the 15-year-old condition. It's hard to tell, but from Figure 7, it looks like the 15-year-old average would be slightly higher than the 7-year-old average, but the difference would be small.

Figure 8. A cross-over interaction.



Try to guess whether there is an interaction or any main effects in Figure 8. The lines are not parallel, so there is likely to be an interaction. Because the lines intersect, this type of interaction is sometimes called a cross-over interaction. It appears that the two black diamonds are not higher or lower than the two open circles, so there is no main effect of teacher expectation. It also appears that the average 7-year-old score is the same as the average 15-year-old score, so a main effect of age is unlikely. In summary, Figure 8 shows no main effect for age, no main effect for expectation, but a cross-over interaction.

Figure 9. Parallel lines.

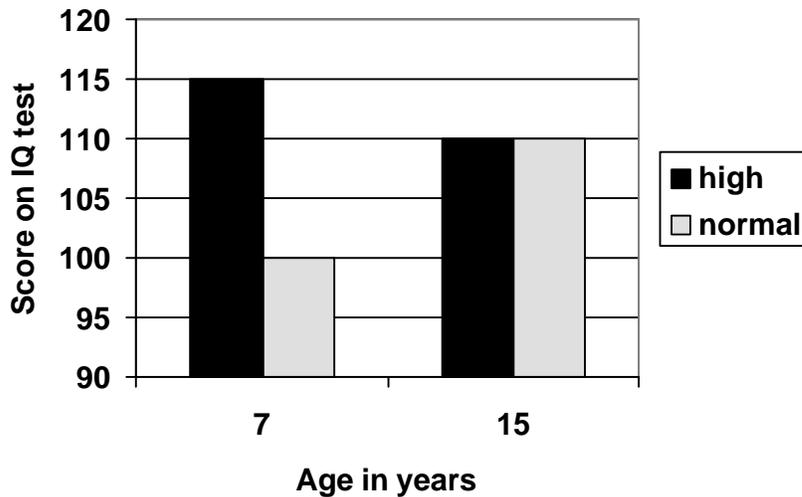


Try the same exercise with Figure 9. The lines are parallel, so there is no interaction. In general, the open circles are higher than the black diamonds, so there is likely to be a main effect of expectations such that normal expectations lead to higher IQ scores than high expectations. Also, the scores for 7-year-olds are higher than the scores for 15-year-olds, suggesting that there is a main effect for age. In summary, Figure 9 shows a main effect of age, a main effect of expectations, and no interaction.

As these examples demonstrate, main effects and interactions are independent of one another. You can have main effects without interactions, interactions without main effects, both, or neither.

Bar Graphs

Figure 10. Effects of age and teacher expectations on IQ scores.



Interpreting bar graphs for main effects and interactions is similar to line graphs, except that identifying interactions is harder and identifying main effects might be easier.

Interactions. To identify an interaction in a bar graph, look for a “difference in differences.” First, look for the difference between high- and normal expectations for 7-year-olds: a difference of about 15 points. Now look at the difference between high and normal expectations for 15-year-olds: a difference of 0 points. The difference of 15 is *different* from the difference of 0. The differences are different. This is the mark of an interaction: the effect of one IV (teacher expectations) is different across different levels of another IV (age).

Main effects. Use the same logic as for the line graphs: are the black bars, in general, higher or lower than the lighter bars? Yes, the black bars are higher. Are the two bars for 7-year-olds higher or lower than the two bars for 15-year-olds? It looks like the bars for 15-year-olds might be slightly higher.