جامعة نيويورك أبوظبي

NYU | ABU DHABI

PSYCH-UH 1004Q: Statistics for Psychology

Class 22: Factorial ANOVA: The experiments and their results

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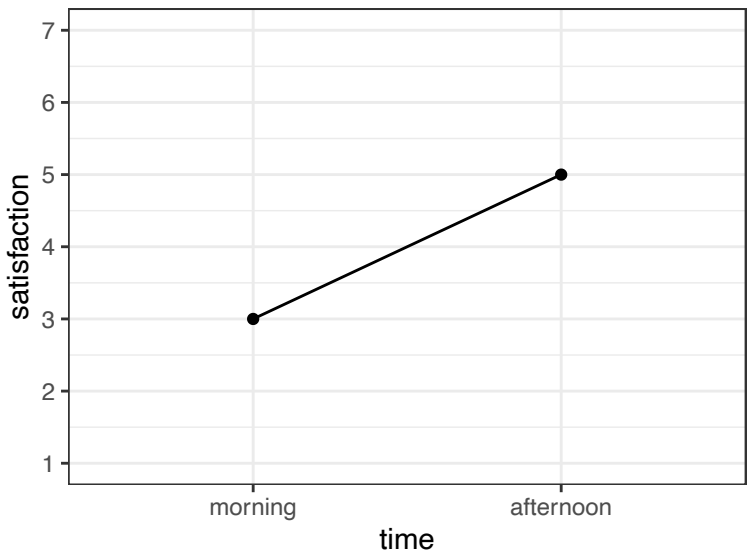
Psychology

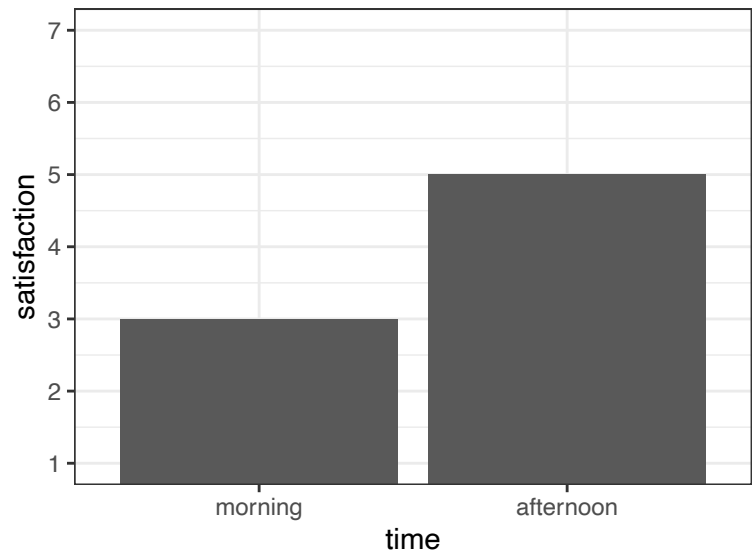
Scientific theories often require two or more independent variables

So far, we've focused on theories with one independent variable

In this course, there is always only one dependent variable. And, so far, we have looked at theories with only one independent variable:

DV		IV
satisfaction with a course meeting time (1-7 scale)	←	time of the course (morning, afternoon)



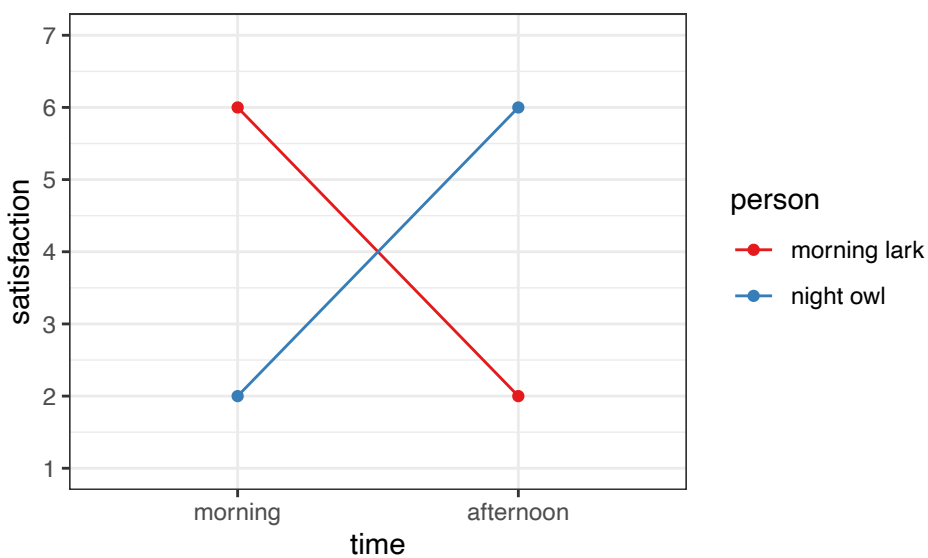


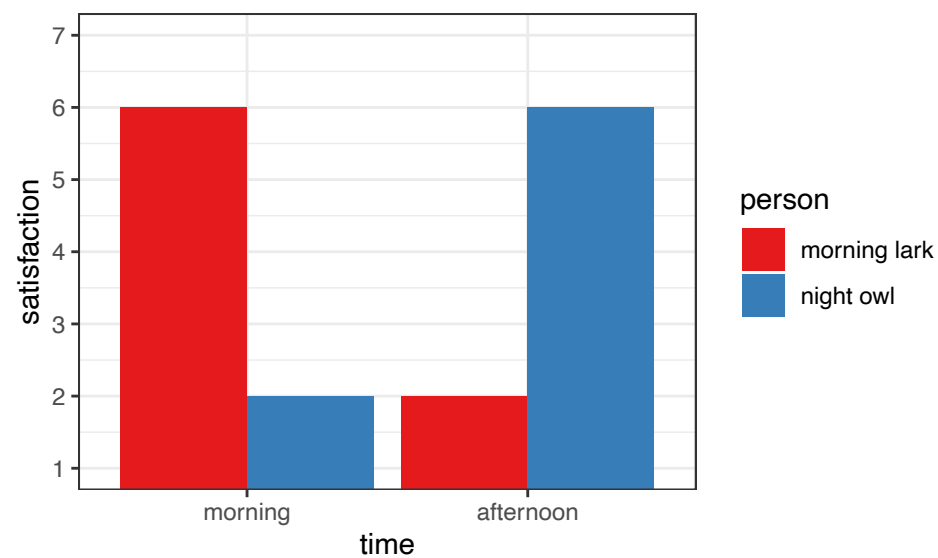
These are two different plots showing the same effect: line or bar.
(I am not adding error bars today to make the patterns clearer. Don't do this!)

But we know theories can be more complicated than that - they can have 2 IVs!

Here is a more complex theory. This theory says that both the time of the course and the type of the person impacts satisfaction with the meeting time.

DV		IV1		IV2
satisfaction with a course meeting time (1-7 scale)	←	time of the course (morning, afternoon)	×	type of person (morning lark, night owl)





These are two different plots showing the same effect: line or bar.
(I am not adding error bars today to make the patterns clearer. Don't do this!)

And, of course more than two!

There is no limit to the number of independent variables that could be relevant for the object that you are studying. We could easily expand our theory of schedule satisfaction to include a third independent variable:

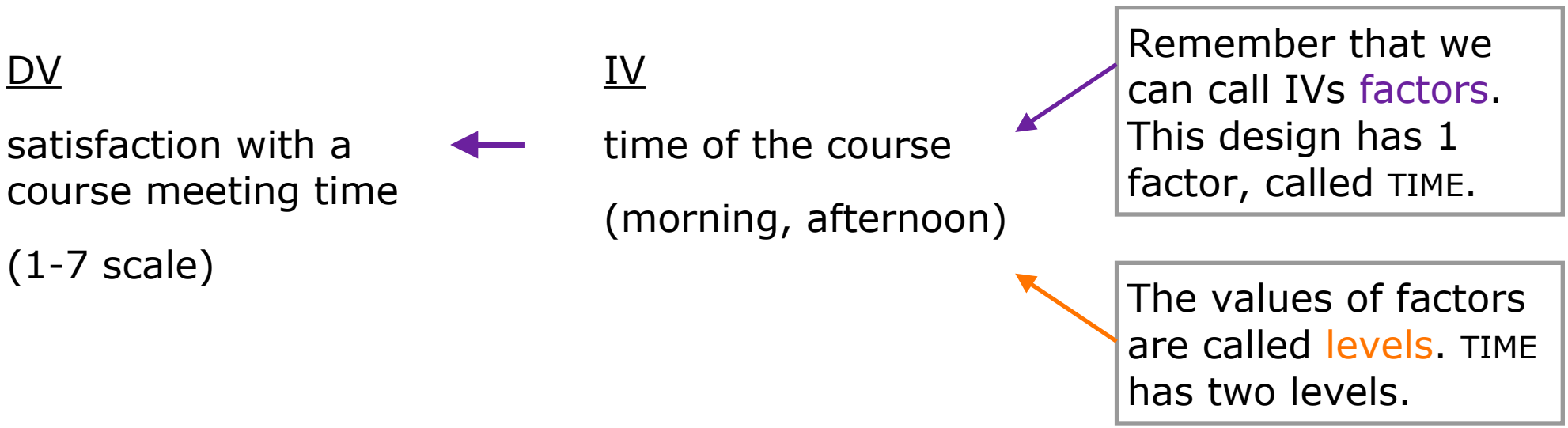
DV		IV1		IV2		IV3
satisfaction	←	time	×	person	×	course immediately before (yes, no)

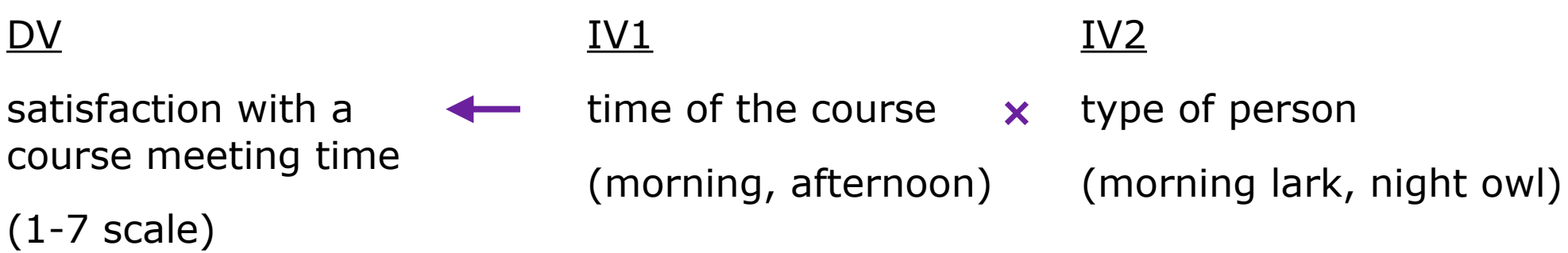
It is easy to see that we can expand this to as many IVs as we'd like in our theory.

But, for today, we will focus on **two IVs**. This is the simplest case, and it will allow us to build up our intuitions about how these theories work!

Some terminology

As we build up more complex theories, and therefore more complex experimental designs, we need to remember our terminology.





This design has two factors. Each factor has two levels.

Some terminology

When we have experimental designs with 2 or more factors, we have a compact notation for conveying the number of factors and levels. It works like this:

2 x 2	This is two factors, each with two levels.
2 x 3	This is two factors, one with two levels and one with three levels.
2 x 2 x 2	This is three factors, each with two levels.
2 x 2 x 3	This is three factors, the first two with two levels, and the third with three levels.

The way this system works is that each factor gets a digit. The value of the digit tells you the number of levels in that factor. This system can be used for any number of factors and levels. (But, in practice, you should probably try to keep your experiments minimal — I rarely recommend a design that is more complicated than a 2x2!)

Let’s explore the basic 2x2 design

Our example experiment

Let's use our course satisfaction theory as an example to better understand 2x2 designs.

DV		IV1		IV2
satisfaction with a course meeting time (1-7 scale)	←	time of the course (morning, afternoon)	×	type of person (morning lark, night owl)

If we were to create an experiment to test this theory, how many groups (conditions) would we need?

	time	**person**
condition/group 1	morning	morning lark
condition/group 2	morning	night owl
condition/group 3	afternoon	morning lark
condition/group 4	afternoon	night owl

This is called a fully crossed design

A fully crossed design is one where each possible combination of the levels of each factor is realized as a condition (or group). We symbolize it with the (cartesian) cross product symbol (x):

time		person
morning	×	morning lark
afternoon		night owl

A 2x2 design yields 4 conditions (or groups). The shortcut here is that you can treat it like multiplication!

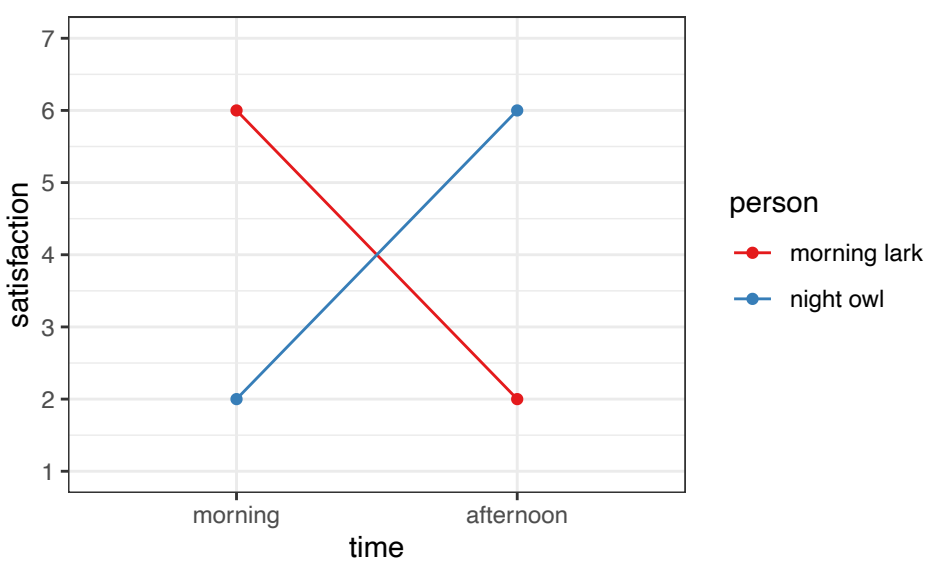
I like to simply list the conditions/groups with the levels that they instantiate from the two factors next to them:

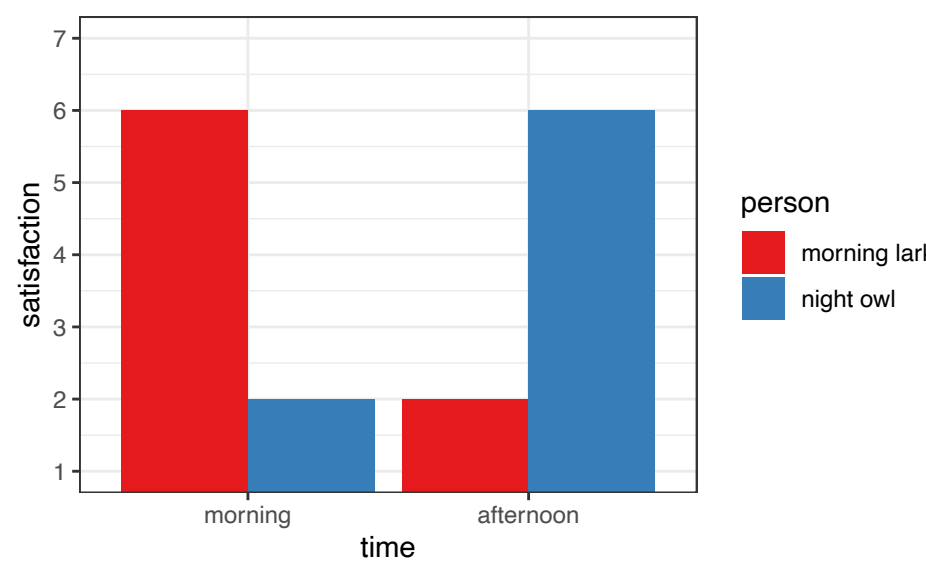
	time	**person**
condition/group 1	morning	morning lark
condition/group 2	morning	night owl
condition/group 3	afternoon	morning lark
condition/group 4	afternoon	night owl

You can see that the plots contain 4 conditions

Take a moment to find each of the four conditions/groups in these example plots that we saw before.

	time	person
condition/group 1	morning	morning lark
condition/group 2	morning	night owl
condition/group 3	afternoon	morning lark
condition/group 4	afternoon	night owl





Plotting the results of a 2x2 design

We have 3 variables that we want to plot: the DV, and 2 IVs. Let's take a moment to see how we do this.

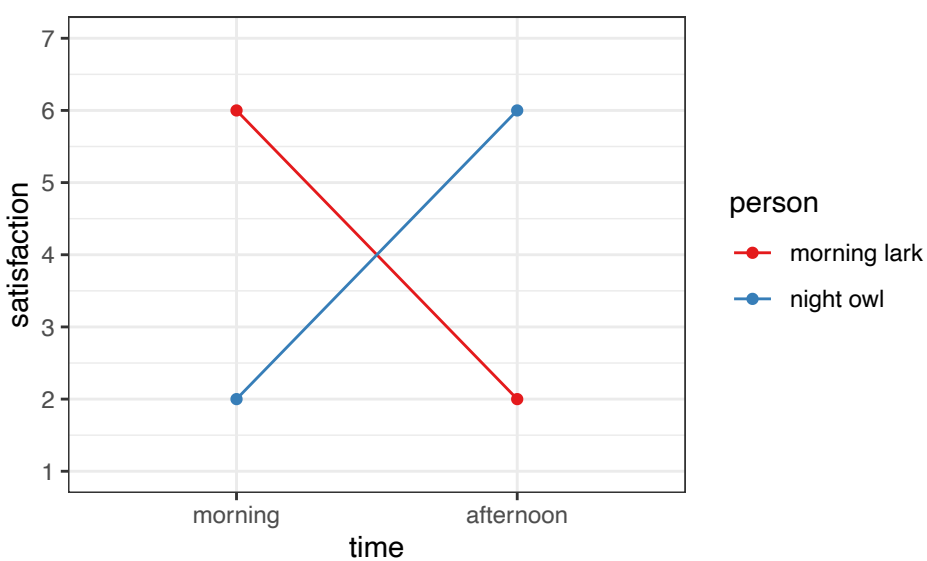
DV		IV1		IV2
satisfaction	←	time	×	person

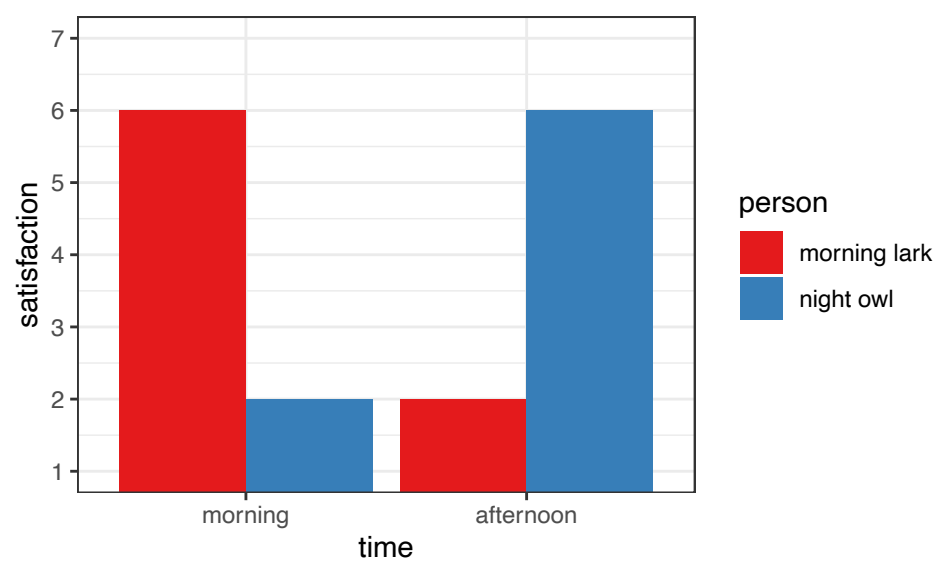
The DV always goes on the y-axis. This is not negotiable.

One IV goes on the x-axis. It is up to you to choose which one.

The other IV is indicated some other way - like color or line type (dashed, etc).

You can create either a line plot (my preference) or a bar plot.





All of the possible outcomes of a 2x2 design

There are three effects in a design with two IVs

If you have 2 factors (IVs), then you can have three effects

1. What is the **main effect** of factor 1 on the dependent variable?

   For our example, this would be the effect of time (morning vs. afternoon) on satisfaction.

2. What is the **main effect** of factor 2 on the dependent variable?

   For our example, this would be the effect of person (lark vs owl) on satisfaction.

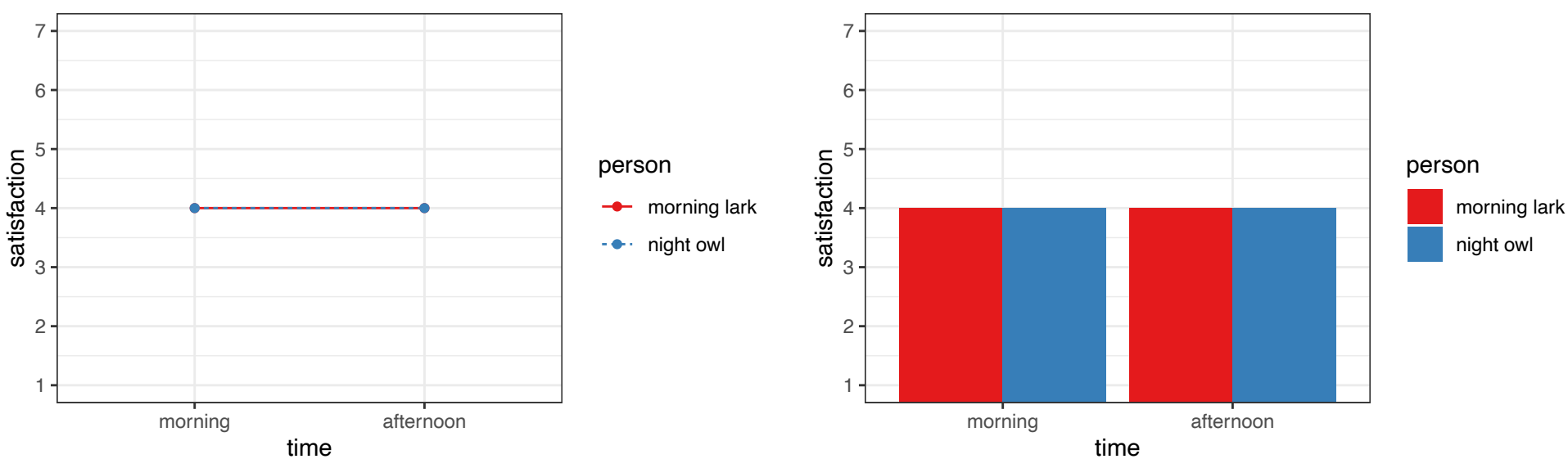
3. What is the effect of the **interaction** of factor 1 and factor 2 on the dependent variable?

   For our example, this is how person (lark vs owl) changes the impact of time (morning vs afternoon) on satisfaction.

No effects at all

The first outcome we can imagine is one in which there is no effect of time, and no effect of person. This means all 4 groups are equally satisfied, so they all give the same rating.

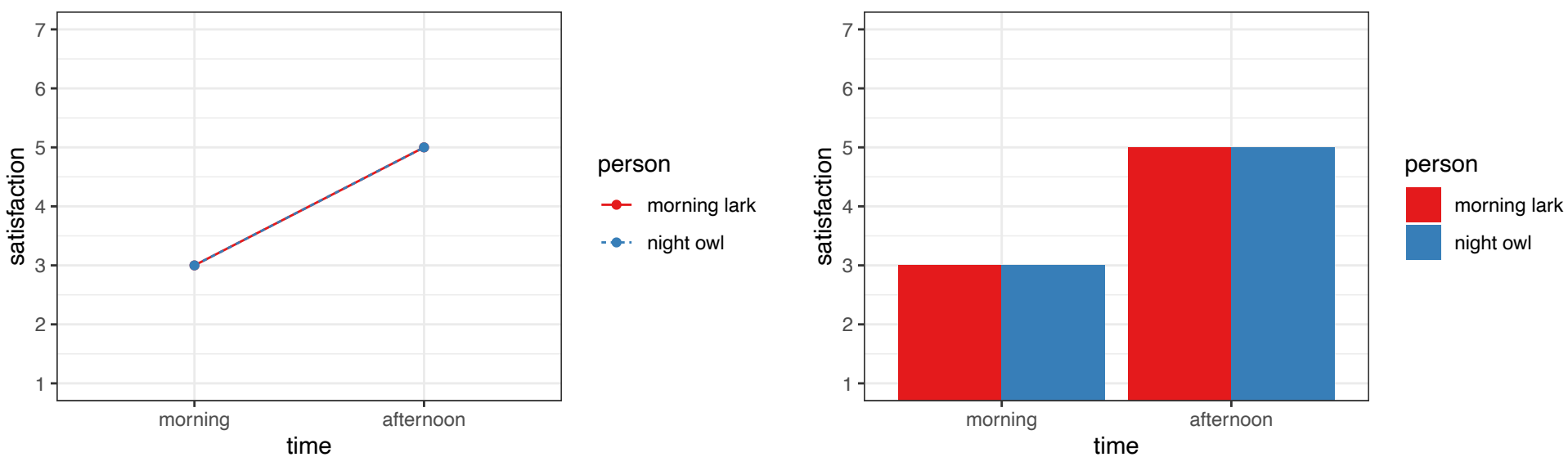
This one is difficult to show in a line plot because the lines will be right on top of each other, so I made the blue line dashed to try to show that it is on top of the red line.



A main effect of time, but not person

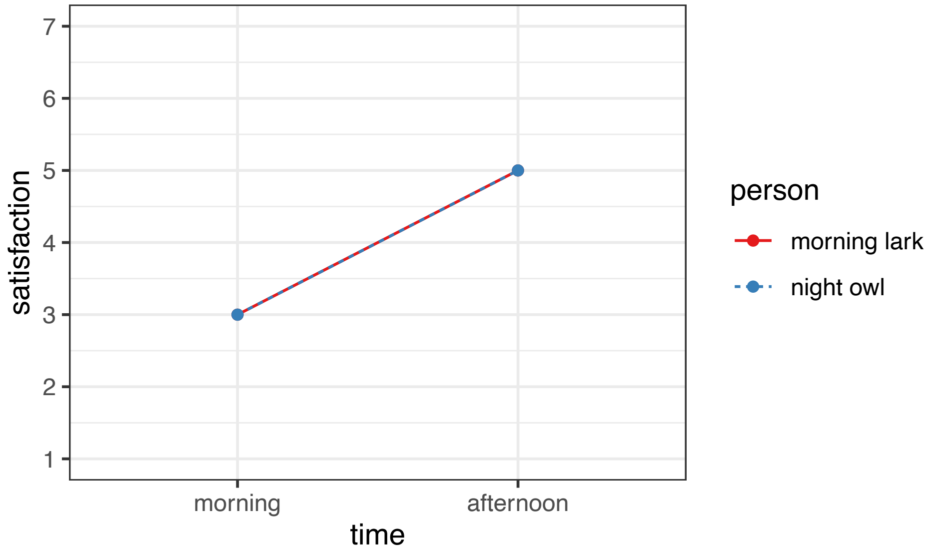
The second outcome we can imagine is one in which there is a main effect of time, but no effect of person, and no interaction between them. This means that both types of people rated morning classes the same, and rated afternoon classes the same.

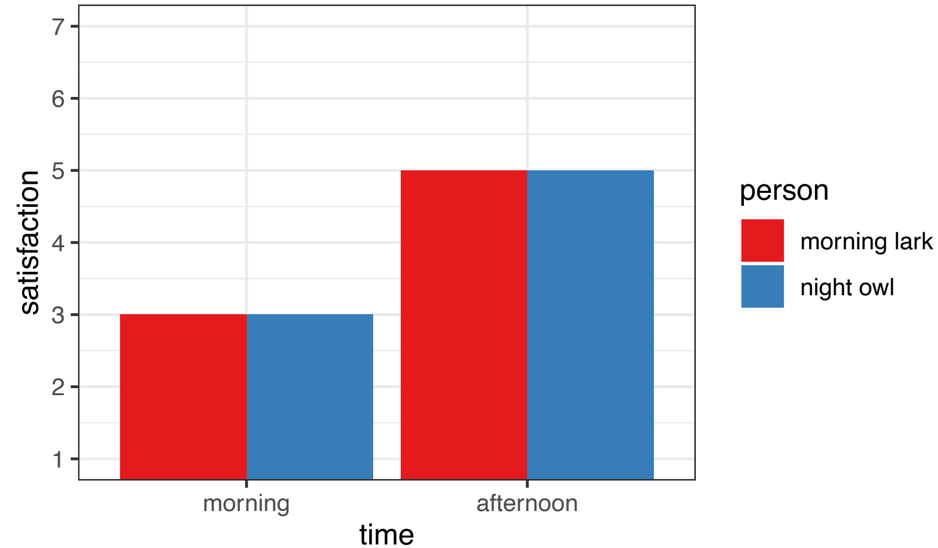
This one is difficult to show in a line plot because the lines will be right on top of each other, so I made the blue line dashed to try to show that it is on top of the red line.

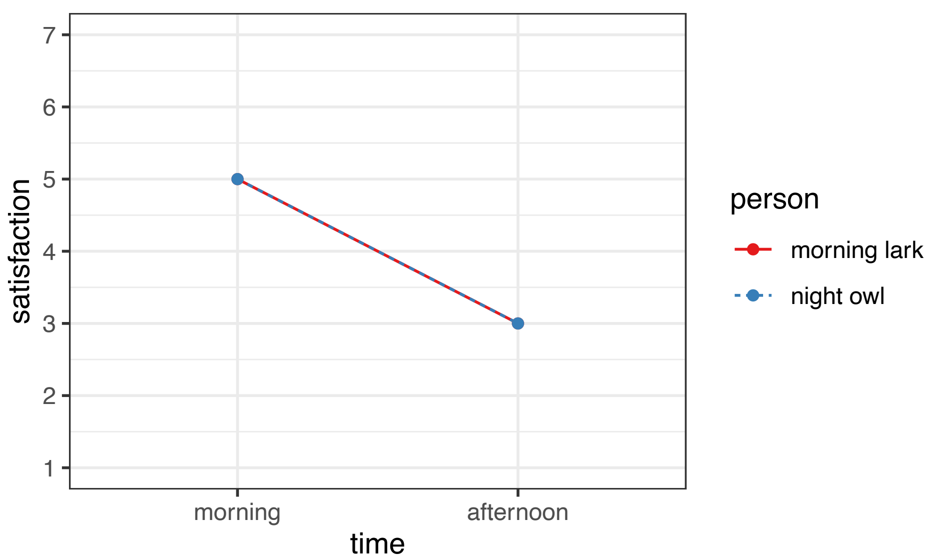


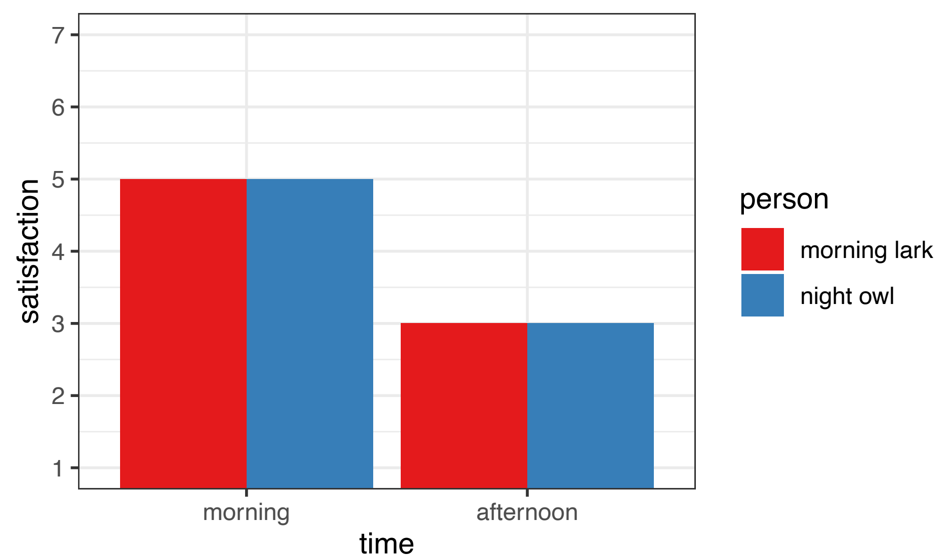
These both show a main effect of time and no main effect of person

With only an effect of time, it could either be that afternoons are better than mornings, or that mornings are better than afternoons.





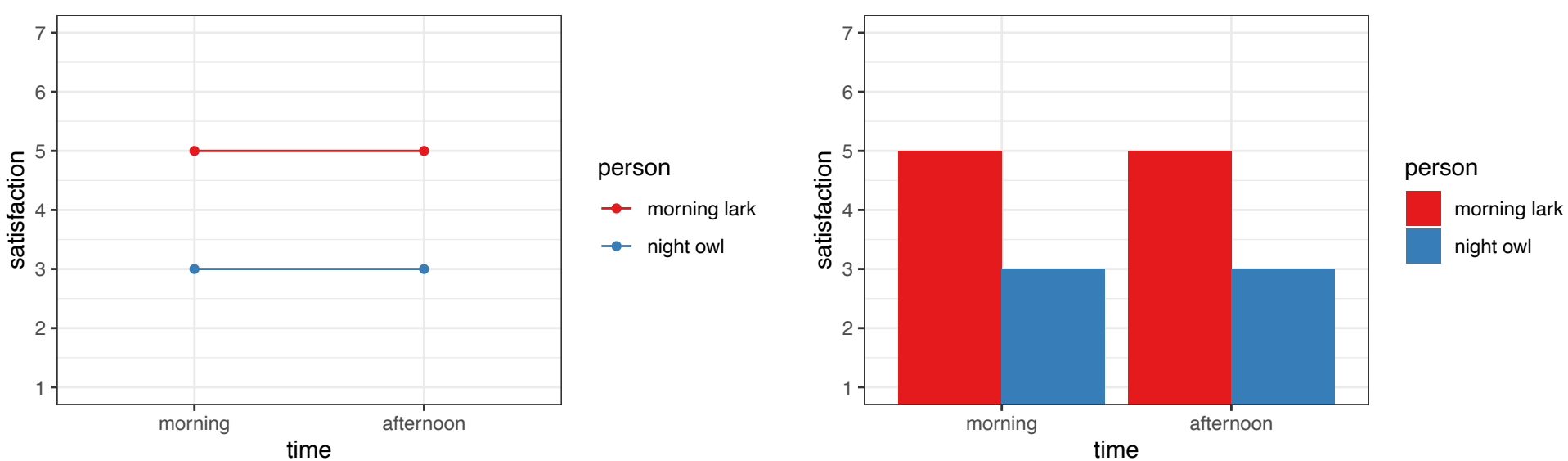




No effect of time, a main effect of person

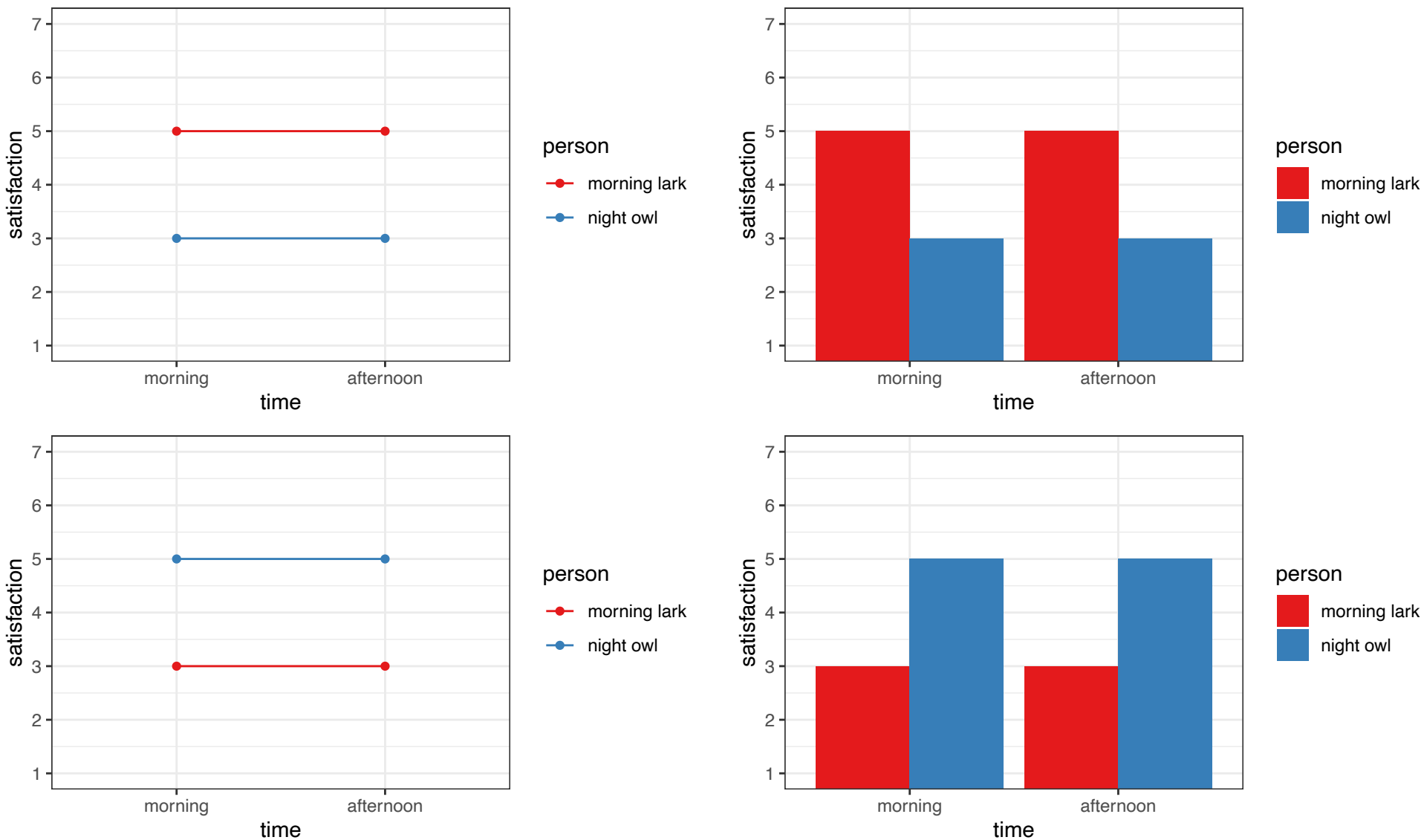
The third outcome we can imagine is one in which there is a no effect of time, but there is a main effect of person, and no interaction between them.

Take a moment to think about what this means. No effect of time means that morning and afternoon classes were rated the same. A main effect of person means that one group generally rates classes higher or lower than the other group. Here it is morning larks rating all classes higher than night owls.



These both show no main effect of time and a main effect of person

With only a main effect of person, it could either be that morning larks rate everything better, or night owls rate everything better.

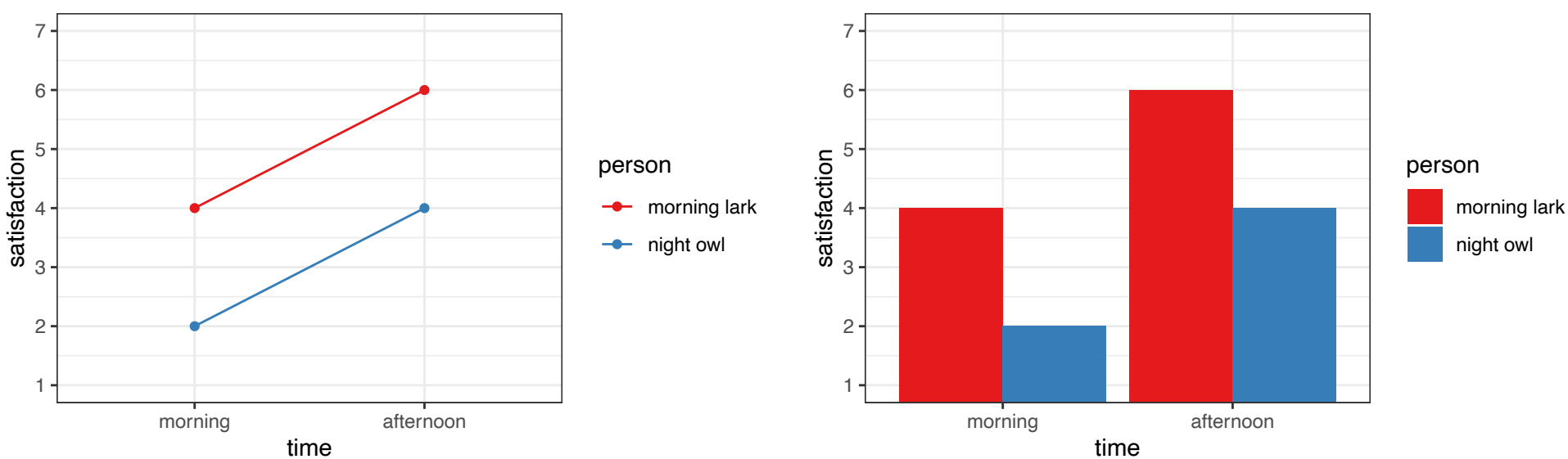


A main effect of time and a main effect of person

The fourth outcome we can imagine is one in which there is a main effect of time, and a main effect of person, but no interaction between them.

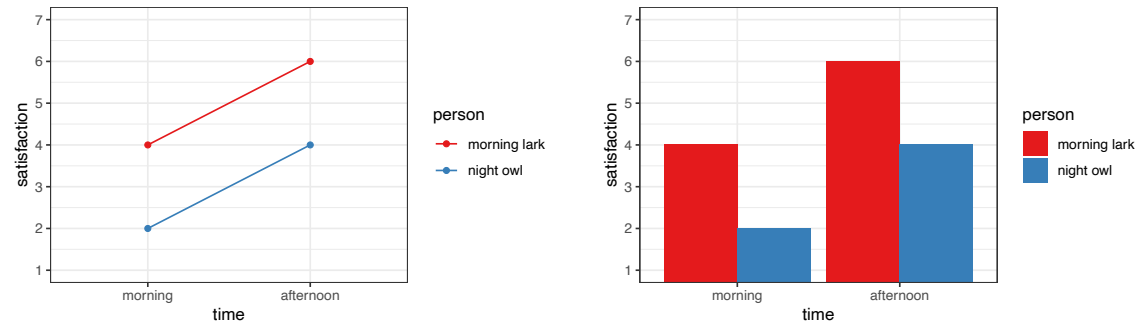
Take a moment to think about what this means. A main effect of time means that there is a difference between morning and afternoon. A main effect of person means that morning larks and night owls are also different.

In this example, everybody likes afternoon classes better than morning classes. Morning larks are generally more satisfied than night owls.

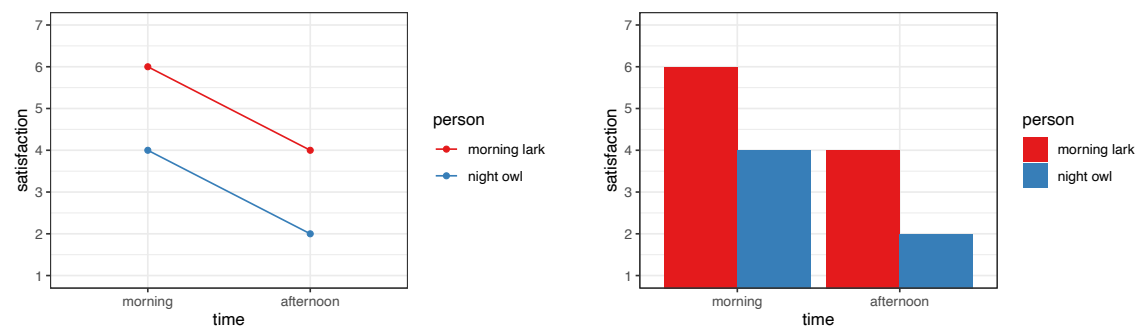


There are four ways to have a main effect of time and a main effect of person

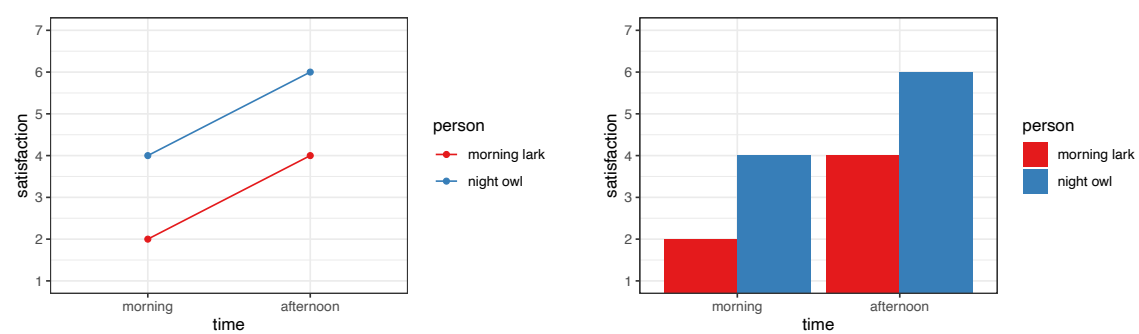
time: morning<afternoon
person: lark>owl



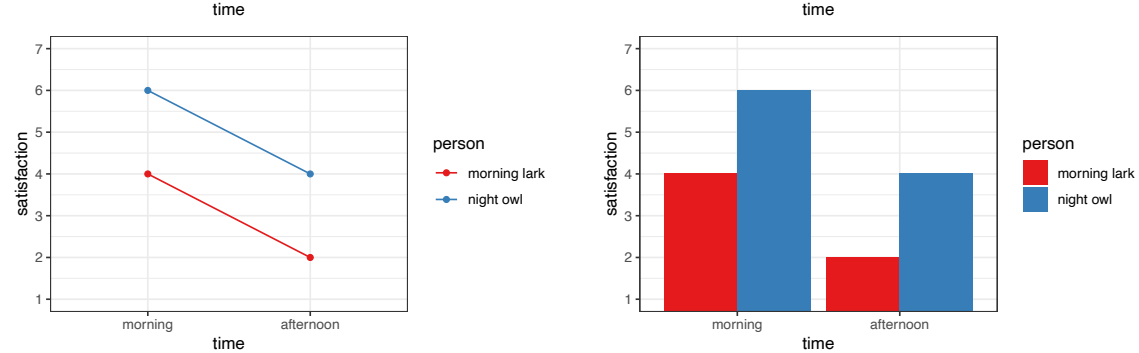
time: morning>afternoon
person: lark>owl



time: morning<afternoon
person: lark<owl



time: morning<afternoon
person: lark<owl

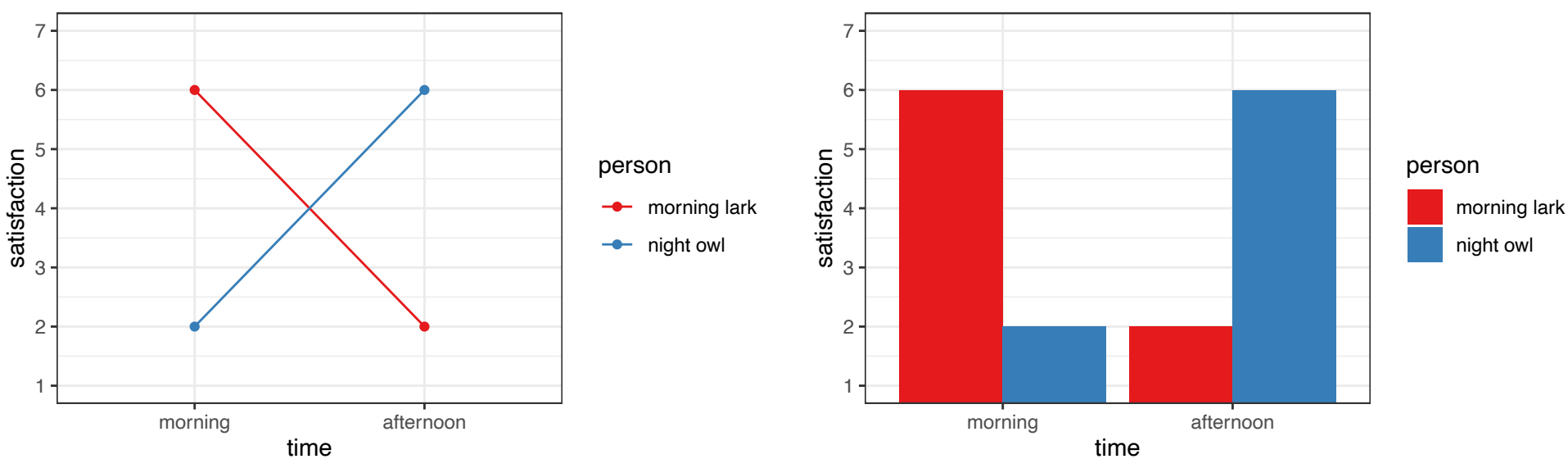


An interaction between time and person

The fifth outcome we can imagine is one in which there is an interaction between time and person. We have actually already seen one example of this earlier.

Remember, the idea of an interaction is that the behavior of the levels of one factor (like time) change based on the other level it is paired with.

In this interaction, we see that morning larks like mornings and dislike afternoons. But night owls are the opposite, they like afternoons and dislike mornings. This is an interaction, because the effect of time changes based on the level of person!



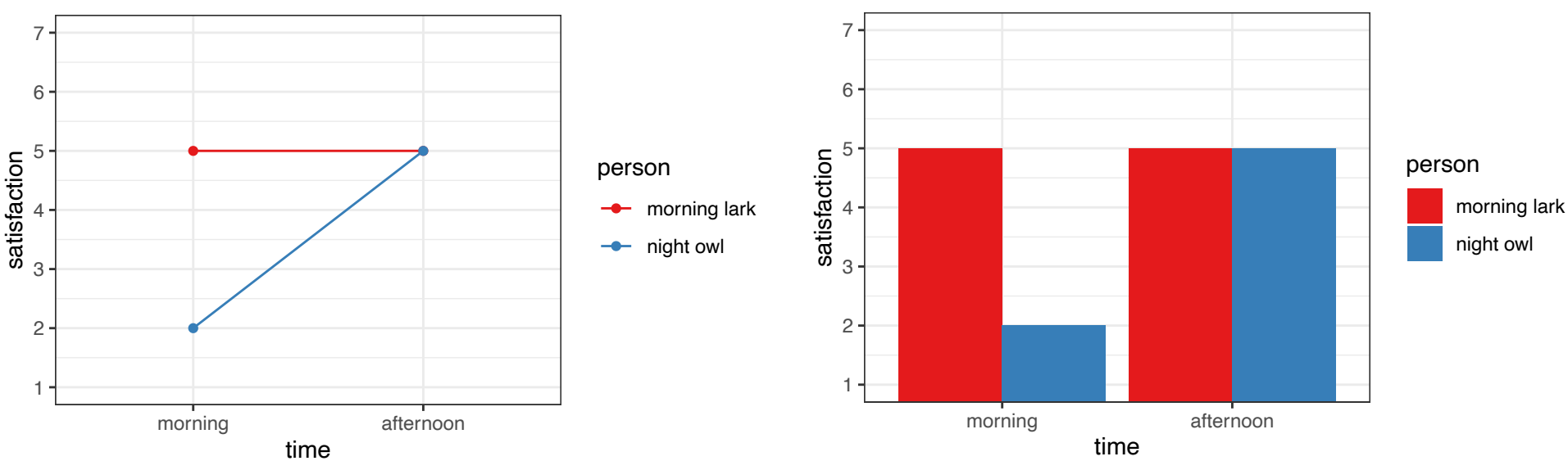
We call this a **disordinal** or **non-monotonic** interaction.

A second type of interaction

There is a second type of interaction. In this one, the lines diverge (they are not parallel), but they do not cross. This means the effects are not going in opposite directions, just that one is larger or smaller than the other.

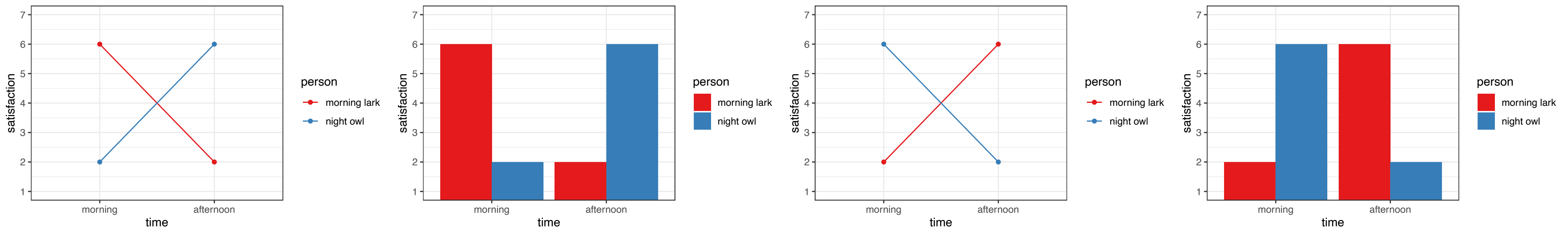
We call this an **ordinal** or **monotonic** interaction.

Here is an ordinal (or monotonic) interaction. It shows morning larks liking both times equally, and night owls dispreferring mornings.

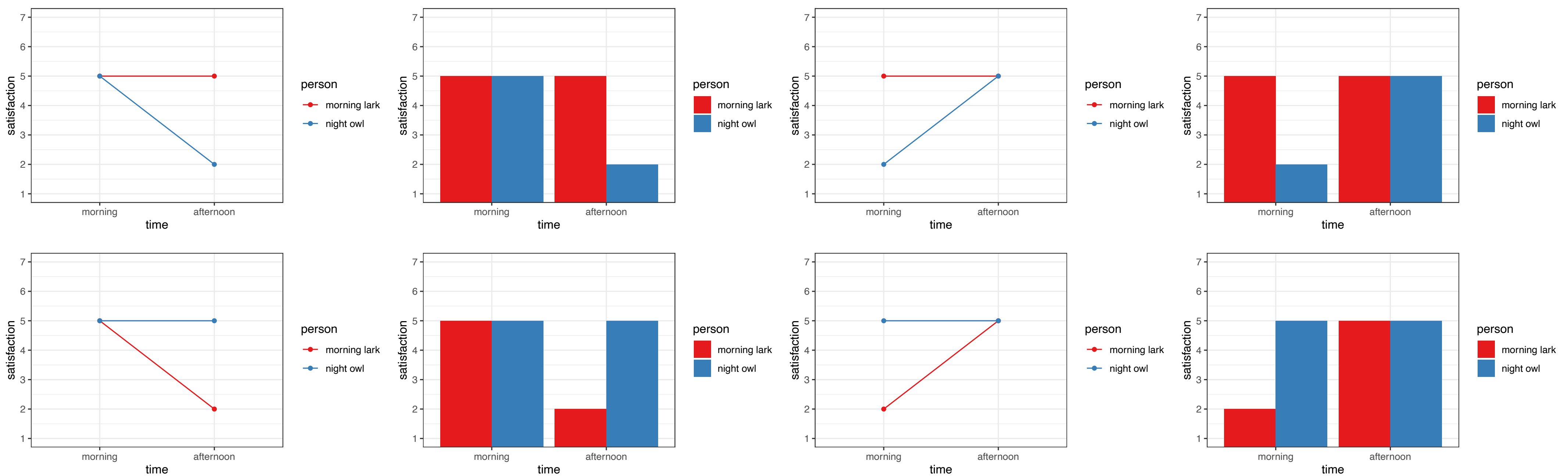


Six arrangements of interactions

Disordinal/non-monotonic interactions look like Xs. There are two options:



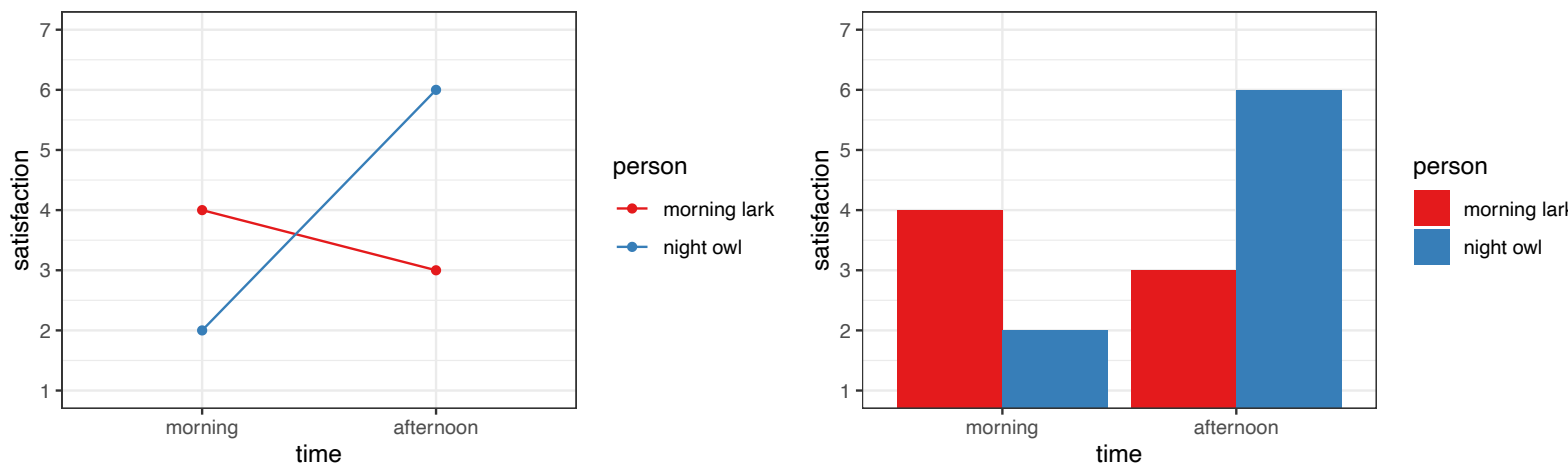
Ordinal/monotonic interactions look like alligator mouths. They can have four options for arranging the groups:



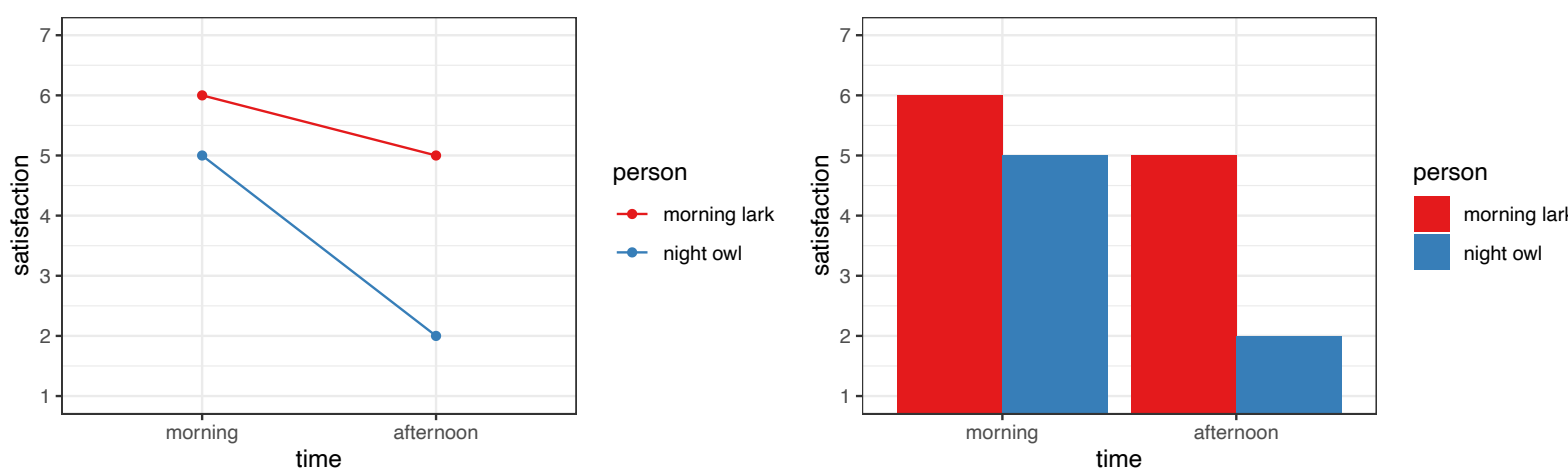
The shapes don’t have to be perfect

In the previous slides, I created the clearest possible instances of interactions. But, in the real world, they may not be so perfect. All that matters is that the basic shape is there.

Disordinal must cross in some way.



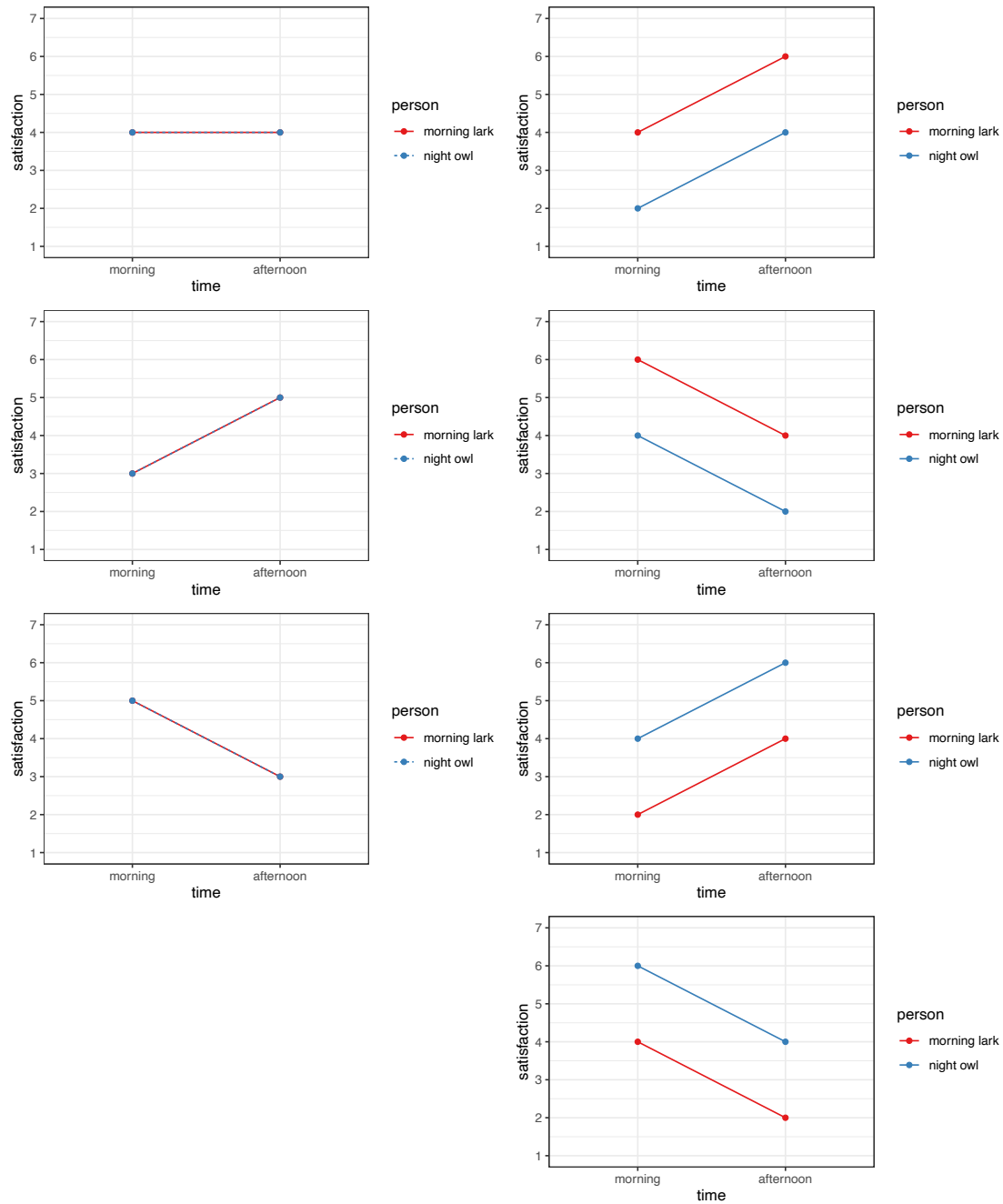
Oordinal must be non-parallel, but also not crossing.



A tip: parallel lines mean **no interaction**

When there is no interaction, the lines will be parallel.

These either show no effect, one main effect, or two main effects. In all cases the lines are parallel. This tells you that there is no interaction.



A tip: non-parallel lines mean **interaction**

When there is an interaction, the lines will be non-parallel.

Obviously, there are multiple ways to be non-parallel. But the overall pattern is that non-parallel lines indicate that there is an interaction.