2-01: GGPlot Introduction

0.1 To-do

- handle ***Source*** issues (especially from plots people have to cycle through)

1 Purpose

- Create a scatterplot in GGPlot
- Modify the scatterplot using components
- Add a second plot

1.1 Code for the lesson

The script for this lesson is here
The Lansing2016Noaa.csv is here

2 GGPlot package

We are going to use the ***GGPlot*** package so we need to add the ggplot2 library to the script.

```
rm(list=ls());                         # clear the Environment tab
library(package=ggplot2);              # include all GGPlot2 functions
```

The second line gives your script access to all of the functions in the GGPlot2 package. Note: ggplot2 is technically the third version of GGPlot – but no one uses the first two versions (ggplot and ggplot1) anymore.

2.1 R-base plots

The script files for lessons in this class that contain plots will have the GGPlot presented in the lesson and, in comments, the R-base plot equivalent. The plan is to eventually add a lesson about R-base plots but, until then, the R-base plots are there FYI.

3 GGPlot components and subcomponents

For many years, RBase was the main plotting tool in R. Rbase was loosely based on the metaphor of drawing plots on a transparency. GGPlot is based more on a building metaphor.

The full list of functions in the GGPlot package is here:
https://ggplot2.tidyverse.org/reference/

In GGPlot, one way to think about the functions is that they are components of a plot. Each time you call a GGPlot function, you are either adding a component to a plot or modifying an existing component. For this class, I refer to the functions in GGPlot as components.

The arguments within the functions can be thought of as subcomponents of the components.

A helpful R resource is the cheat sheets, which exists for many popular packages – the cheat sheet for GGPlot2 is on this page:
https://rstudio.github.io/cheatsheets/html/data-visualization.html

4 Create plot data using GGPlot

We are going to create a scatterplot in GGPlot using data from ***Lansing2016NOAA.csv***

```
# read in CSV file and save the content to weatherData
weatherData = read.csv(file="data/Lansing2016NOAA.csv");
```

The scatterplot will be average temperature *(**avgTemp** column)* vs. humidity (***relHum*** column).

The code to create a scatterplot using GGPlot is:

```
#### Part 1: Create a scatterplot ####
plot1 = ggplot( data=weatherData ) +
  geom_point( mapping=aes(x=avgTemp, y=relHum) );
plot(plot1);
```

Source the script and this plot appears:

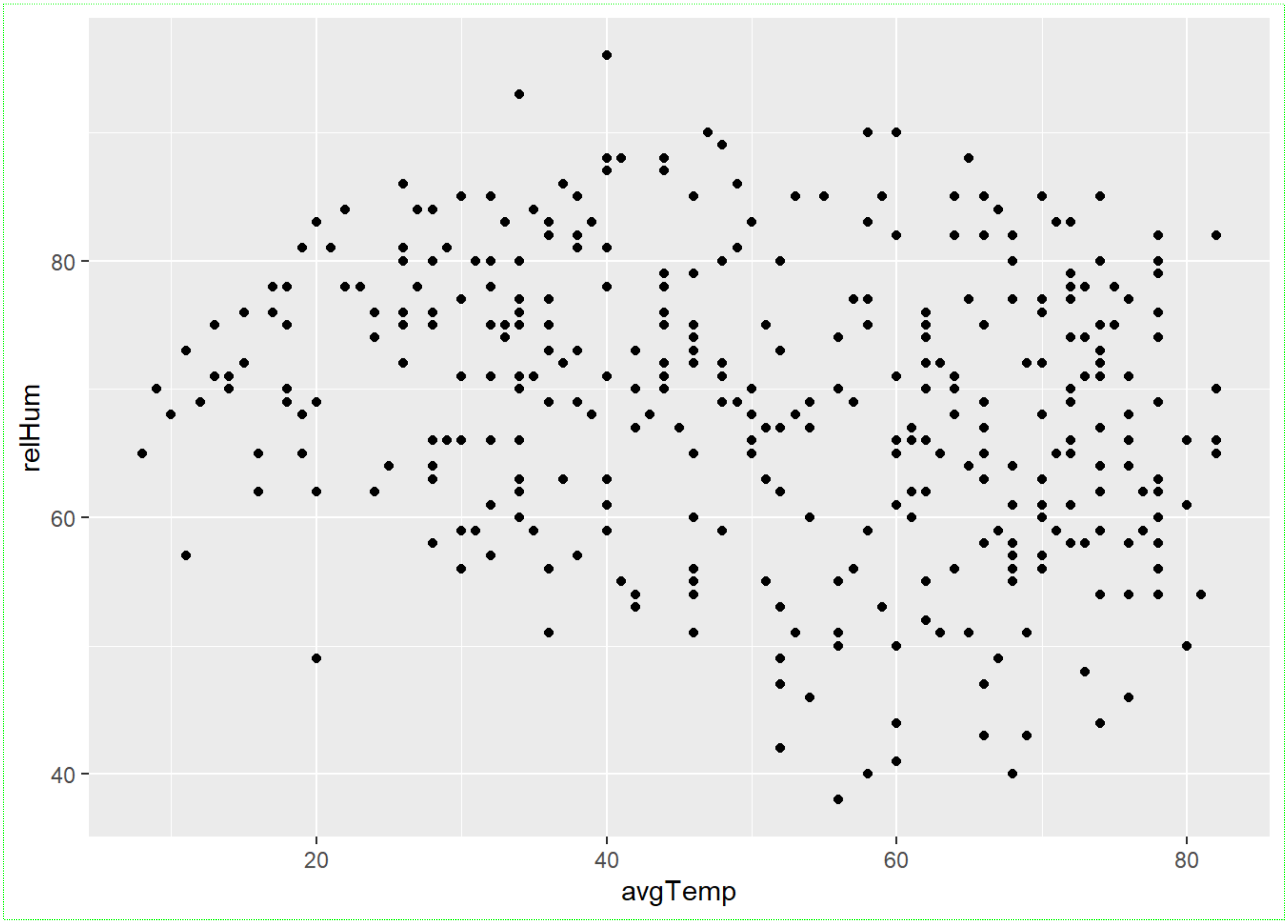
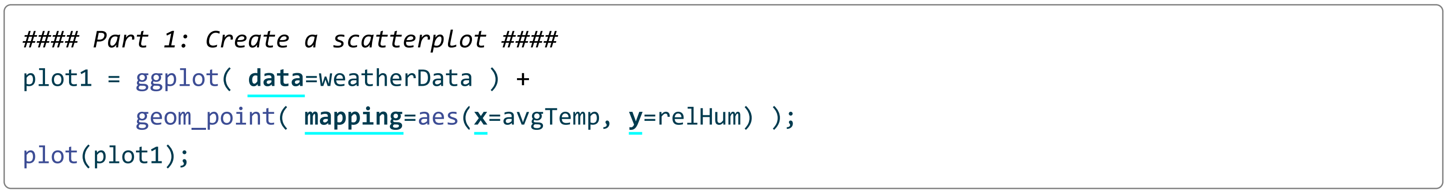


Figure 1: Our first plot using GGPlot – note that the x and y-axis labels match the mapped name

4.1 Taking out argument names

Below, the argument names are highlighted:



```
#### Part 1: Create a scatterplot ####
plot1 = ggplot( data=weatherData ) +
        geom_point( mapping=aes(x=avgTemp, y=relHum) );
plot(plot1);
```

Figure 2: Argument names used in ggplot call

We can remove the argument names and, in this case, the script will render the same plot:

```
#### Part 2: Same scatterplot without argument names ####
plot2 = ggplot( weatherData ) +
        geom_point( aes(avgTemp, relHum) );
plot(plot2);   # same as plot1
```

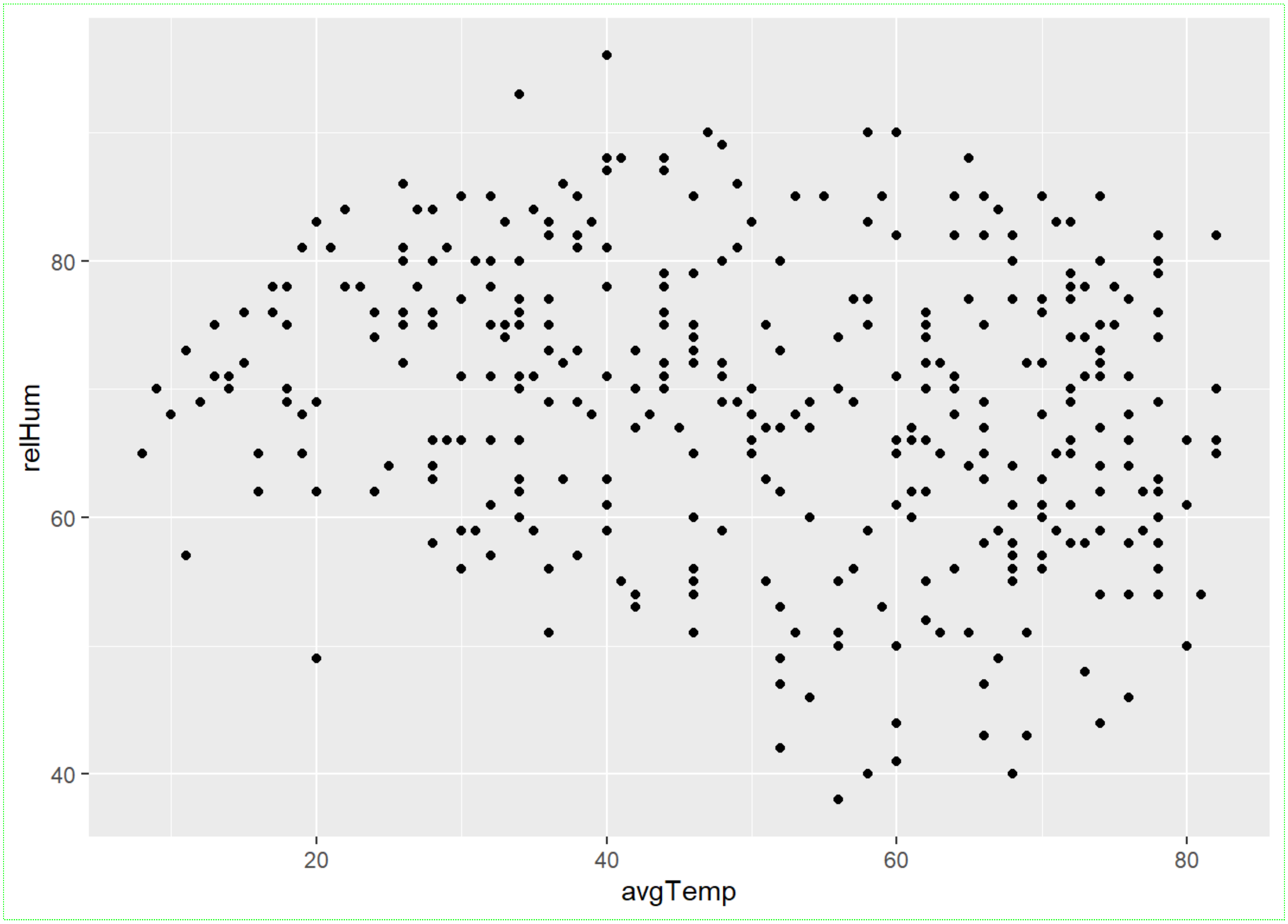


Figure 3: Taking out argument names, in this case, produces the same plot

4.2 Benefits of using argument names

You will often see people skip the argument names and, for the example above, this works. But it only works because we only used the default arguments for each function and used the arguments in the same order as they appeared in the function.

In this class, we will (almost always) use argument names because using argument names:

- makes the code more intuitive to the reader – and making code more intuitive should (almost always) take precedence over saving space
- means that you can order the arguments however you want
- avoids bad assumptions about the ordering of arguments and their default values

The one exception where we will not use argument names is:

```
plot(plot1)   # no argument name used here
```

instead of

```
plot(x=plot1) # x is the argument name
```

There are multiple functions in R and GGPlot where ***x*** is used as the first argument name in a function, and it often refers to the data being passed in to the function. This is not intuitive when plotting because ***x*** is also used to refer to x-axis data.

We will use the argument name ***x*** when ***x*** refers to an axis (e.g., ***x=avgTemp***) but not when ***x*** refers generically to data (e.g., ***x=plotData***) as shown in Figure 2.

5 Components of a GGPlot

Let's take a more detailed look at the three lines of code that created the scatterplot.

The function ***ggplot()*** creates a canvas area where all the components will be drawn. The argument ***data*** gives the data that will be used by the components, which is set to the data frame ***weatherData***:

```
plot1 = ggplot( data=weatherData ) +
        geom_point( mapping=aes(x=avgTemp, y=relHum) );
plot(plot1);
```

Next, we add the scapperplot component ***geom_point()***, and map the ***x*** and ***y*** axis to the ***avgTemp*** and ***relHum*** columns from ***weatherData***:

```
plot1 = ggplot( data=weatherData ) +
        geom_point( mapping=aes(x=avgTemp, y=relHum) );
plot(plot1);
```

The canvas, which contains a scatterplot, is saved to a variable named ***plot1:***

```
plot1 = ggplot( data=weatherData ) +
        geom_point( mapping=aes(x=avgTemp, y=relHum) );
plot(plot1);
```

note: **plot1** is a **List** variable – **List** variable will be covered in a later lesson

And then ***plot()*** is used to display the canvas saved in ***plot1***:

```
plot1 = ggplot( data=weatherData ) +
        geom_point( mapping=aes(x=avgTemp, y=relHum) );
plot(plot1);
```

5.1 GGPlot components

In GGPlot, you initialize a canvas and then add components to the canvas. The (**+**) symbol is used to add components, and you can string multiple components together. In the above example, there is the canvas initialization function, ***ggplot()***, and one component, ***geom_point()***:

1) ***ggplot()*** is used to initialize a GGPlot canvas with the data from ***weatherData***:

```
plotData = ggplot( data=weatherData ) +
           geom_point( mapping=aes(x=avgTemp, y=relHum) );
```

2) ***geom_point()*** is a plotting component that creates a scatterplot

```
plotData = ggplot( data=weatherData ) +
           geom_point( mapping=aes(x=avgTemp, y=relHum) );
```

5.2 GGPlot mapping and aesthetics (aes)

Most plotting components in GGPlot contain a subcomponent called **mapping**. ***mapping*** describes the relationship between the data and the plot. Or, another way to put it, ***mapping*** describes what data gets represented on the plot (in the above case, ***avgTemp*** and ***relHum***) and how the data gets represented (***avgTemp*** on x-axis, ***relHum*** on y-axis):

```
plotData = ggplot( data=weatherData ) +
           geom_point( mapping=aes(x=avgTemp, y=relHum) );
```

The ***mapping*** is set to a mapping element called an aesthetic (***aes***). The concept of an aesthetic comes into play when we are generating legends and creating data categories, which is a topic we delve much deeper into in the GGPlot class.

6 Adding more components to the canvas

Let's say we want to make the three following modifications to the plot:

1. add a title and change the axes labels
2. change the numeric tick marks on the y-axis
3. change the direction of the x-axis labels

To do this we will add three new components to the canvas:

1. ***labs()*** – label component
2. ***scale_x_continuous()*** – x-scaling component (there is a corresponding y-scaling component)
3. ***theme()*** – theme component

We add components using (**+**) and subcomponents are the arguments within the components:

```
#### Part 3: Adding components to the plot ####
```

```
plot3 = ggplot( data=weatherData )
         +
  geom_point( mapping=aes(x=avgTemp, y=relHum) )
         +
  labs( title="Humidity vs Temperature",
        subtitle="Lansing, MI -- 2016",
        x = "Average Temperatures (Fahrenheit)",
        y = "Relative Humidity")
         +
  scale_x_continuous( breaks = seq(from=10, to=80, by=10) )
         +
  theme( axis.text.x=element_text(angle=90, vjust=0.5) );
plot(plot3);
```

Trap: Putting the (+) on the next line

And ***plot3*** includes the three new components:

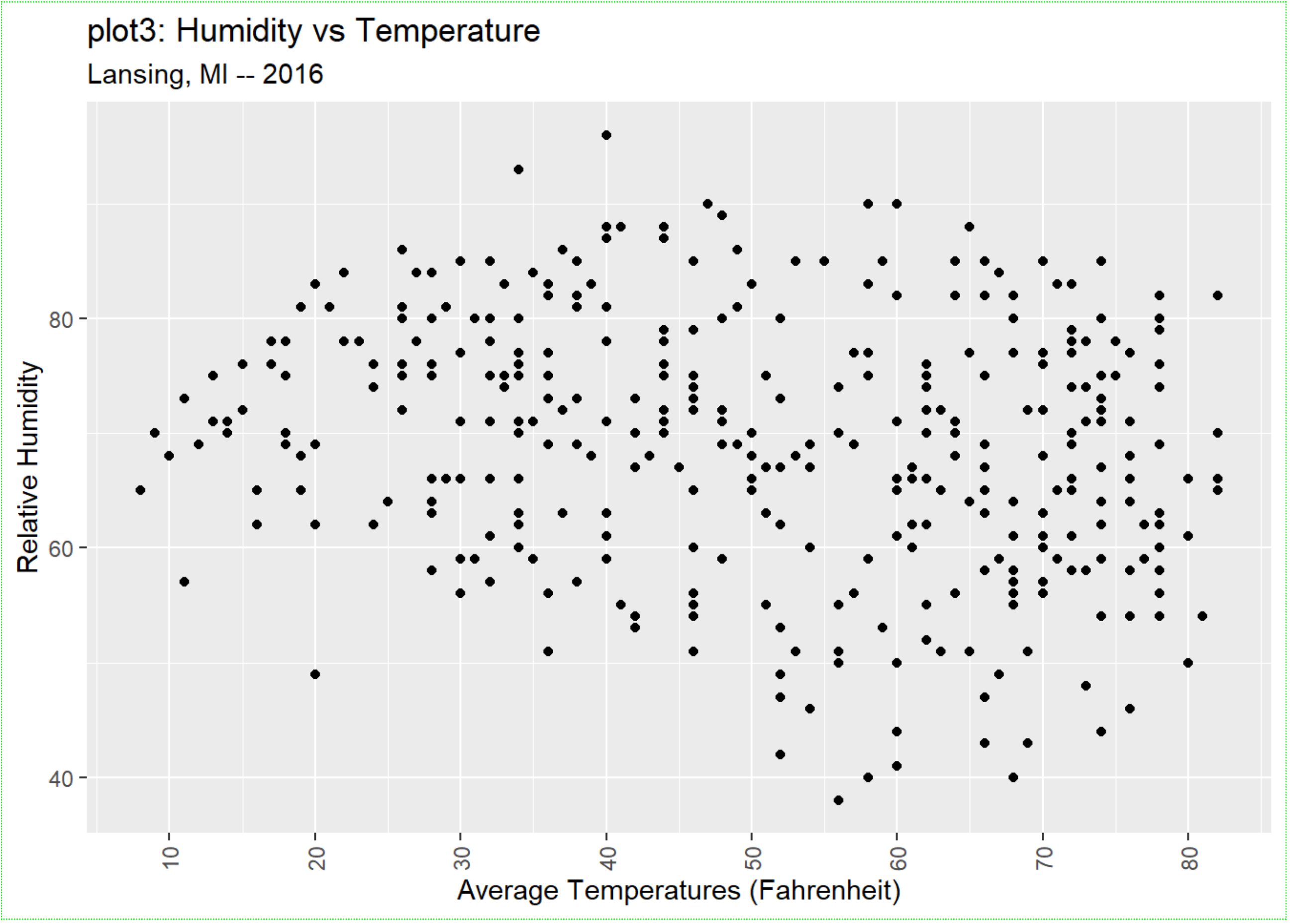


Figure 4: Scatterplot with a few added components

6.1 The Components in detail

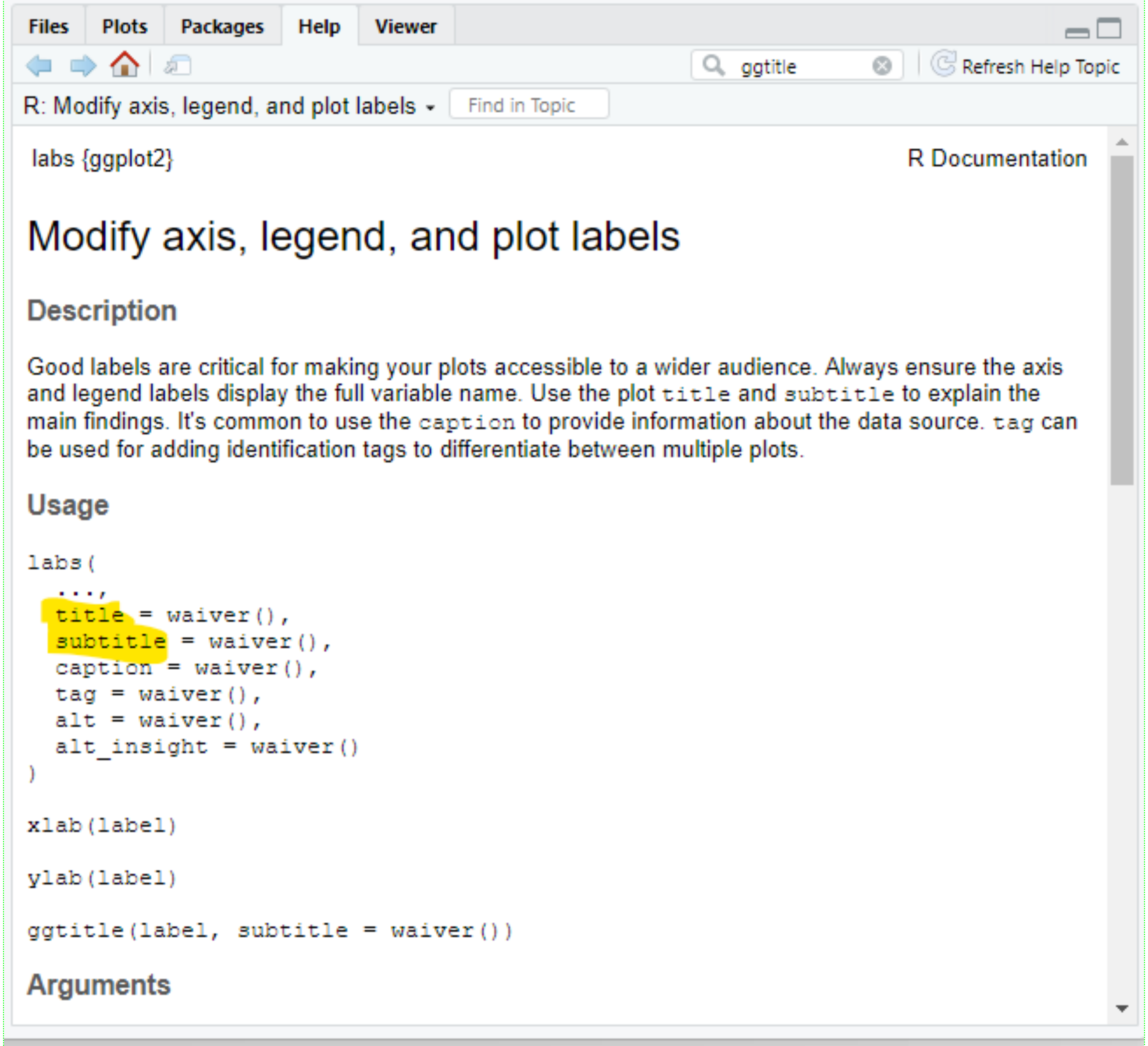
```
  labs( title="Humidity vs Temperature",
        subtitle="Lansing, MI -- 2016",
        x = "Average Temperatures (Fahrenheit)",
        y = "Relative Humidity") +
```

When we search in the ***Help*** tab for ***labs()*** (Figure 5) we see that it has many subcomponents (or arguments) including:

- ***label***: the title
- ***subtitle***: a secondary title

A couple of notes about the information in the ***Help***:

- There are many ways to add axes labels, ***labs()*** sort of merges all of these methods into one component. Because of this, the ***Help*** section does not explicitly show the ***x*** and ***y*** arguments (although, the examples below do). This is one area where the ***Help*** could do a better job reflecting the functionality of a function.
- ***waiver()*** is the default value given by the plotting function.



labs {ggplot2}	R Documentation

Modify axis, legend, and plot labels

Description

Good labels are critical for making your plots accessible to a wider audience. Always ensure the axis and legend labels display the full variable name. Use the plot `title` and `subtitle` to explain the main findings. It's common to use the `caption` to provide information about the data source. `tag` can be used for adding identification tags to differentiate between multiple plots.

Usage

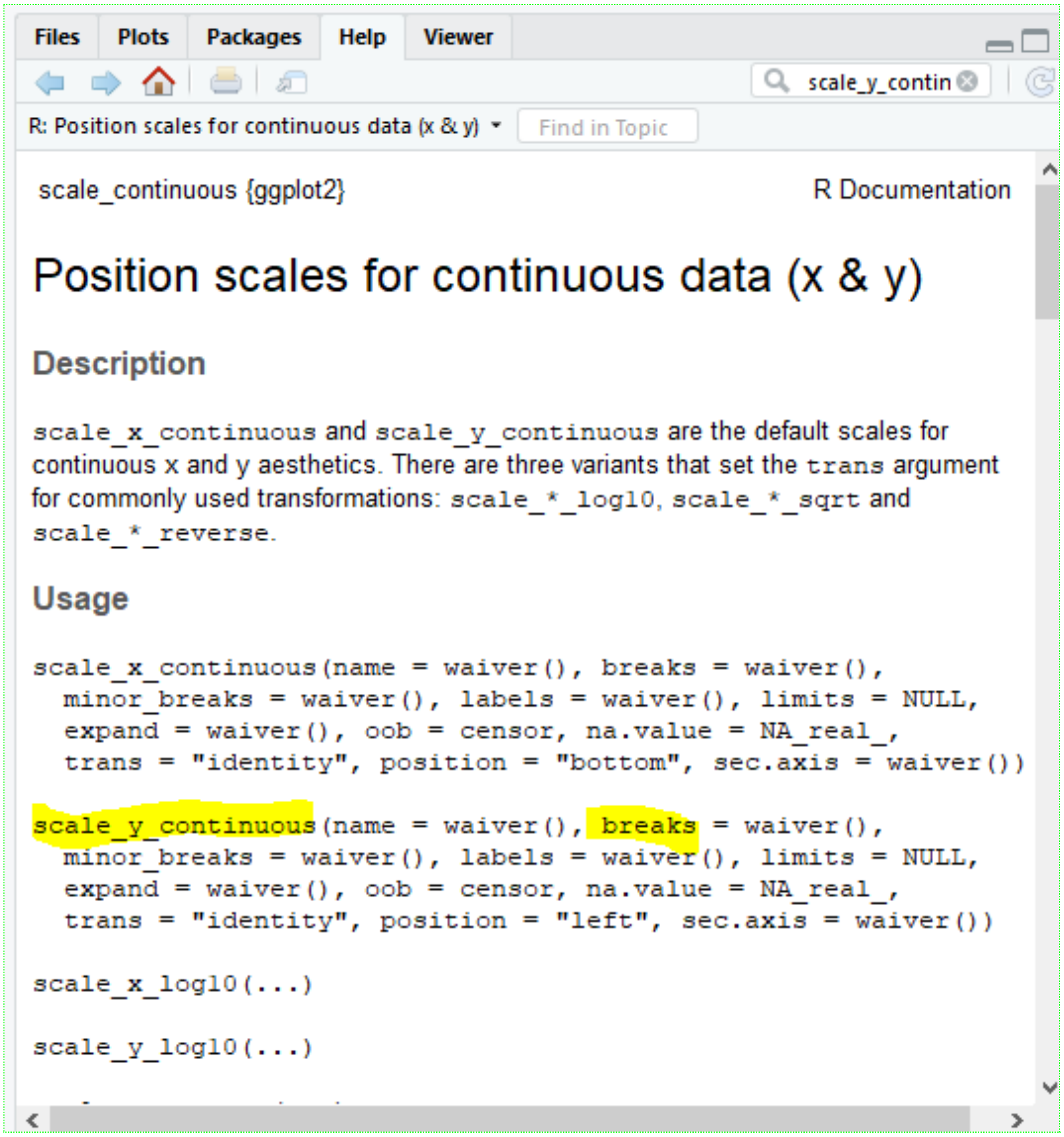
```
labs(
  ...,
  title = waiver(),
  subtitle = waiver(),
  caption = waiver(),
  tag = waiver(),
  alt = waiver(),
  alt_insight = waiver()
)

xlab(label)

ylab(label)

ggtitle(label, subtitle = waiver())
```

Arguments

Figure 5: Using the Help tab in RStudio to find info about GGPlot components

```
scale_x_continuous( breaks = seq(from=10, to=80, by=10) )
```

scale_x_continuous() is the component used when you want to modify an x-axis that has continuous values. There are many subcomponents (Figure 6) that can be changed in ***scale_x_continuous()*** and the corresponding ***scale_y_continuous()***. We modified one subcomponent, ***breaks***, by setting it to a sequence from **10** to ***80*** with numeric values place at intervals of **10**.



scale_continuous {ggplot2} R Documentation

Position scales for continuous data (x & y)

Description

`scale_x_continuous` and `scale_y_continuous` are the default scales for continuous x and y aesthetics. There are three variants that set the `trans` argument for commonly used transformations: `scale_*_log10`, `scale_*_sqrt` and `scale_*_reverse`.

Usage

```
scale_x_continuous(name = waiver(), breaks = waiver(),
  minor_breaks = waiver(), labels = waiver(), limits = NULL,
  expand = waiver(), oob = censor, na.value = NA_real_,
  trans = "identity", position = "bottom", sec.axis = waiver())

scale_y_continuous(name = waiver(), breaks = waiver(),
  minor_breaks = waiver(), labels = waiver(), limits = NULL,
  expand = waiver(), oob = censor, na.value = NA_real_,
  trans = "identity", position = "left", sec.axis = waiver())

scale_x_log10(...)

scale_y_log10(...)
```

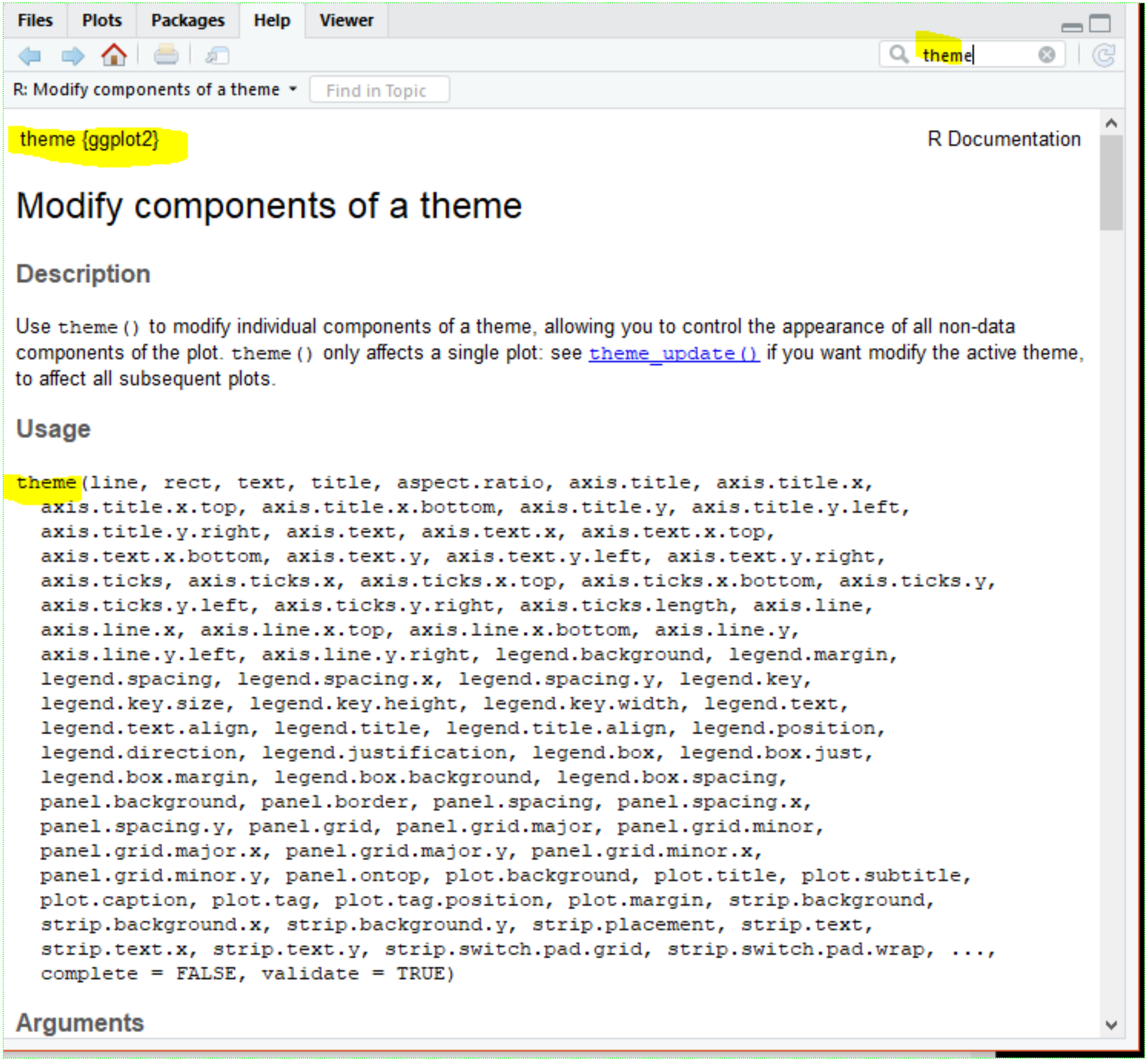
Figure 6: scale_x_continuous help page

note: ***scale_x_discrete()*** is used to modify an x-axis with discrete values.

```
theme( axis.text.x=element_text(angle=90, vjust=0.5) )
```

In this example we changed one subcomponent in ***theme()*** called ***axis.text.x*** and set it to an ***element_text()*** that modifies the text by rotating it to an ***angle*** of **90** degrees and centering the text (***vjust=0.5***). Note: the default for **vjust is 1,** which means the text will be vertically justified to the bottom. **vjust=0** means the text will be vertically justified to the top.

Broadly speaking, ***theme()*** is used to make modifications that are not data related to the canvas (the plots and the background). ***theme()*** is probably the most used component in GGPlot, and we could spend many lessons going through all the subcomponents of ***theme()***.



theme {ggplot2}

R Documentation

Modify components of a theme

Description

Use `theme()` to modify individual components of a theme, allowing you to control the appearance of all non-data components of the plot. `theme()` only affects a single plot: see `theme_update()` if you want modify the active theme, to affect all subsequent plots.

Usage

```
theme(line, rect, text, title, aspect.ratio, axis.title, axis.title.x,
  axis.title.x.top, axis.title.x.bottom, axis.title.y, axis.title.y.left,
  axis.title.y.right, axis.text, axis.text.x, axis.text.x.top,
  axis.text.x.bottom, axis.text.y, axis.text.y.left, axis.text.y.right,
  axis.ticks, axis.ticks.x, axis.ticks.x.top, axis.ticks.x.bottom, axis.ticks.y,
  axis.ticks.y.left, axis.ticks.y.right, axis.ticks.length, axis.line,
  axis.line.x, axis.line.x.top, axis.line.x.bottom, axis.line.y,
  axis.line.y.left, axis.line.y.right, legend.background, legend.margin,
  legend.spacing, legend.spacing.x, legend.spacing.y, legend.key,
  legend.key.size, legend.key.height, legend.key.width, legend.text,
  legend.text.align, legend.title, legend.title.align, legend.position,
  legend.direction, legend.justification, legend.box, legend.box.just,
  legend.box.margin, legend.box.background, legend.box.spacing,
  panel.background, panel.border, panel.spacing, panel.spacing.x,
  panel.spacing.y, panel.grid, panel.grid.major, panel.grid.minor,
  panel.grid.major.x, panel.grid.major.y, panel.grid.minor.x,
  panel.grid.minor.y, panel.ontop, plot.background, plot.title, plot.subtitle,
  plot.caption, plot.tag, plot.tag.position, plot.margin, strip.background,
  strip.background.x, strip.background.y, strip.placement, strip.text,
  strip.text.x, strip.text.y, strip.switch.pad.grid, strip.switch.pad.wrap, ...,
  complete = FALSE, validate = TRUE)
```

Arguments

Figure 7: theme() component help page (yes, there is a lot there!)

6.2 For more help with components

A good place to find more information about components in GGPlot is the **Help** tab in the lower-right corner of RStudio. The ***Help*** tab provides information directly from https://ggplot2.tidyverse.org/reference/, which is the official webpage for GGPlot.

7 Getting rid of the grey (themes)

The default GGplot theme, which uses the gray background, is not my favorite. Luckily, GGPlot makes it easy to change the theme. The components that do this, called ***complete themes***, are on this page. I will change to the black-white theme:

```
#### Part 4: Changing the theme ####
plot4 = ggplot( data=weatherData ) +
  geom_point( mapping=aes(x=avgTemp, y=relHum) ) +
  labs( title="Humidity vs Temperature",
        subtitle="Lansing, MI -- 2016",
        x = "Average Temperatures (Fahrenheit)",
        y = "Relative Humidity") +
  scale_x_continuous( breaks = seq(from=10, to=80, by=10) ) +
  theme_bw() +
  theme( axis.text.x=element_text(angle=90, vjust=0.5) );
plot(plot4);
```

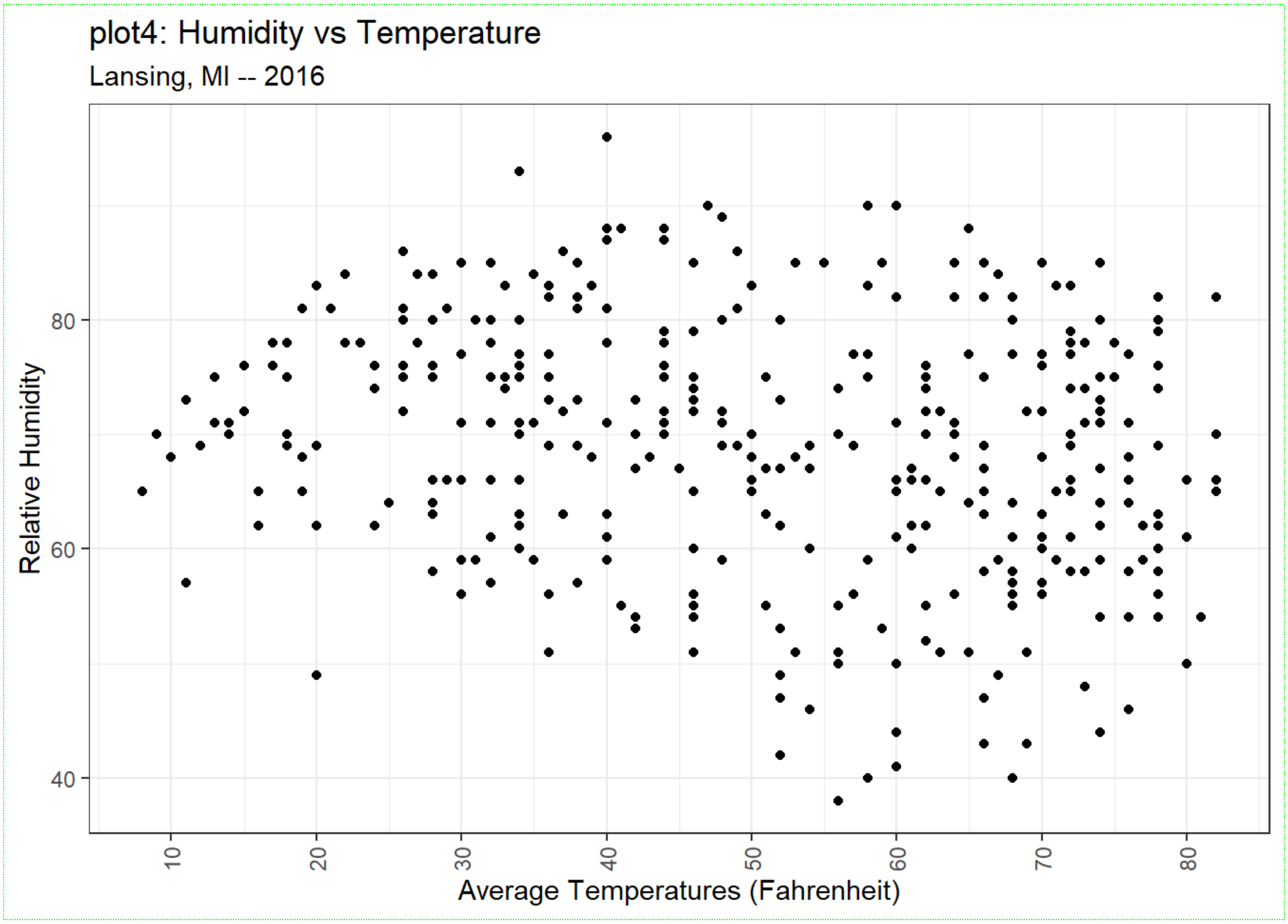


Figure 8: Setting the GGPlot theme to black and white

7.1 Complete themes must come before theme changes

A complete theme (e.g., **theme_bw()**) overwrites the whole theme for the canvas. This means it will overwrite any ***theme*** changes you previously made. In this code, ***theme_bw()*** overwrite the ***theme()*** on the line before:

```
#### Part 5: Changing the complete theme --- oops, undoes theme ####
plot5 = ggplot( data=weatherData ) +
  geom_point( mapping=aes(x=avgTemp, y=relHum) ) +
  labs( title="Humidity vs Temperature",
        subtitle="Lansing, MI -- 2016",
        x = "Average Temperatures (Fahrenheit)",
        y = "Relative Humidity") +
  scale_x_continuous( breaks = seq(from=10, to=80, by=10) ) +
  theme( axis.text.x=element_text(angle=90, vjust=0.5) ) +
  theme_bw();  # this complete theme change will remove the theme change above
plot(plot5);
```

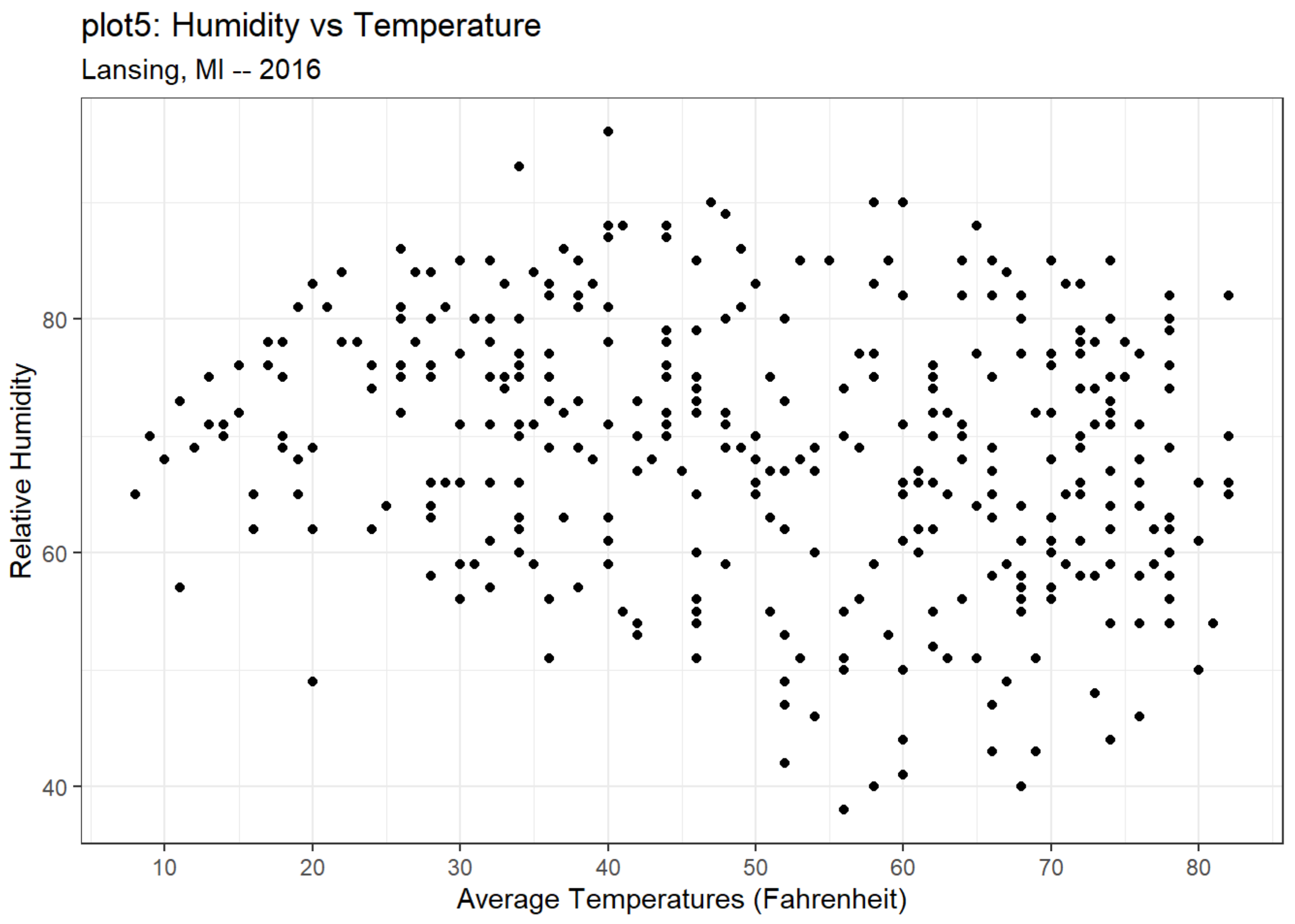


Figure 9: The complete theme change removed the theme change above it (the axis labels are no longer at 90 degrees)

8 Adding a second plot (a linear regression)

Next, we will add a regression line to the canvas. This is done using the plotting component ***geom_smooth()***.

geom_smooth() adds data to the plot area so we need to use the ***mapping*** subcomponent to tell ***GGPlot*** what data is being added to the plot area and how. In this case, we are mapping ***relHum*** vs. ***avgTemp***.

We also add the ***method*** subcomponent to ***geom_smooth()*** to set the smoothing method we will use on the data. In this case, linear model (***lm***).

```
#### Part 6: Adding a regression line ####
plot6 = ggplot( data=weatherData ) +
  geom_point( mapping=aes(x=avgTemp, y=relHum) ) +
  geom_smooth( mapping=aes(x=avgTemp, y=relHum),
               method="lm" ) +
  labs( title="Humidity vs Temperature",
        subtitle="Lansing, MI -- 2016",
        x = "Average Temperatures (Fahrenheit)",
        y = "Relative Humidity") +
  scale_x_continuous( breaks = seq(from=10, to=80, by=10) ) +
  theme_bw() +
  theme( axis.text.x=element_text(angle=90, vjust=0.5) );
plot(plot6);
```

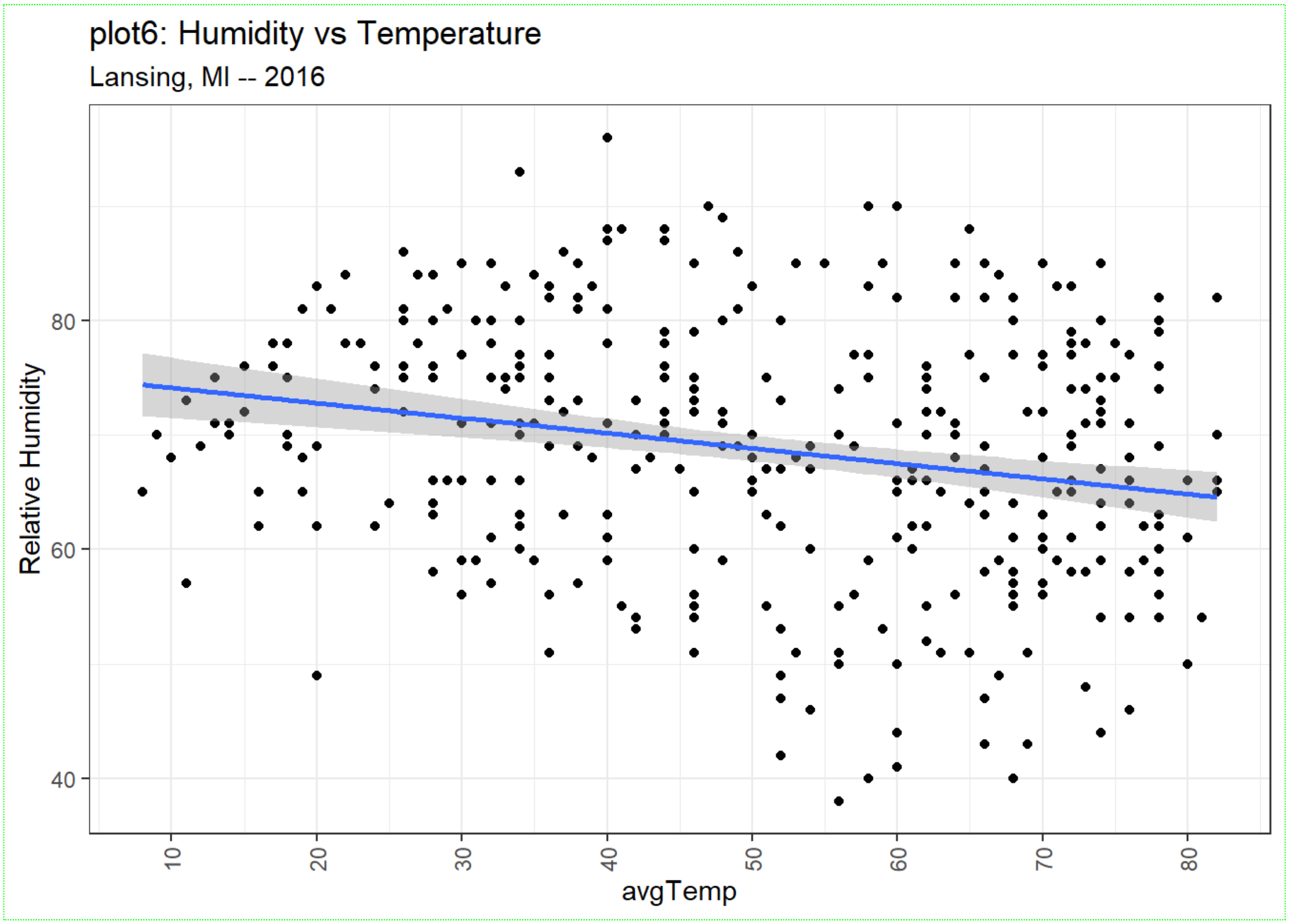


Figure 10: Adding a linear model component

8.1 Overlapping plots

When two plots overlap, as the linear model and the scatterplot do in Figure 10, the component that is added later to the ***ggplot()*** canvas overlaps the earlier component. So, in the above case, the linear model overlaps the scatterplot.

To have the scatterplot overlap the linear model, just switch the two components around:

```
#### Part 7: Reversing the overlapping plots ####
plot7 = ggplot( data=weatherData ) +
  geom_smooth( mapping=aes(x=avgTemp, y=relHum),
               method="lm" ) +
  geom_point( mapping=aes(x=avgTemp, y=relHum) ) +
  labs( title="Humidity vs Temperature",
        subtitle="Lansing, MI -- 2016",
        x = "Average Temperatures (Fahrenheit)",
        y = "Relative Humidity") +
  scale_x_continuous( breaks = seq(from=10, to=80, by=10) ) +
  theme_bw() +
  theme( axis.text.x=element_text(angle=90, vjust=0.5) );
plot(plot7);
```

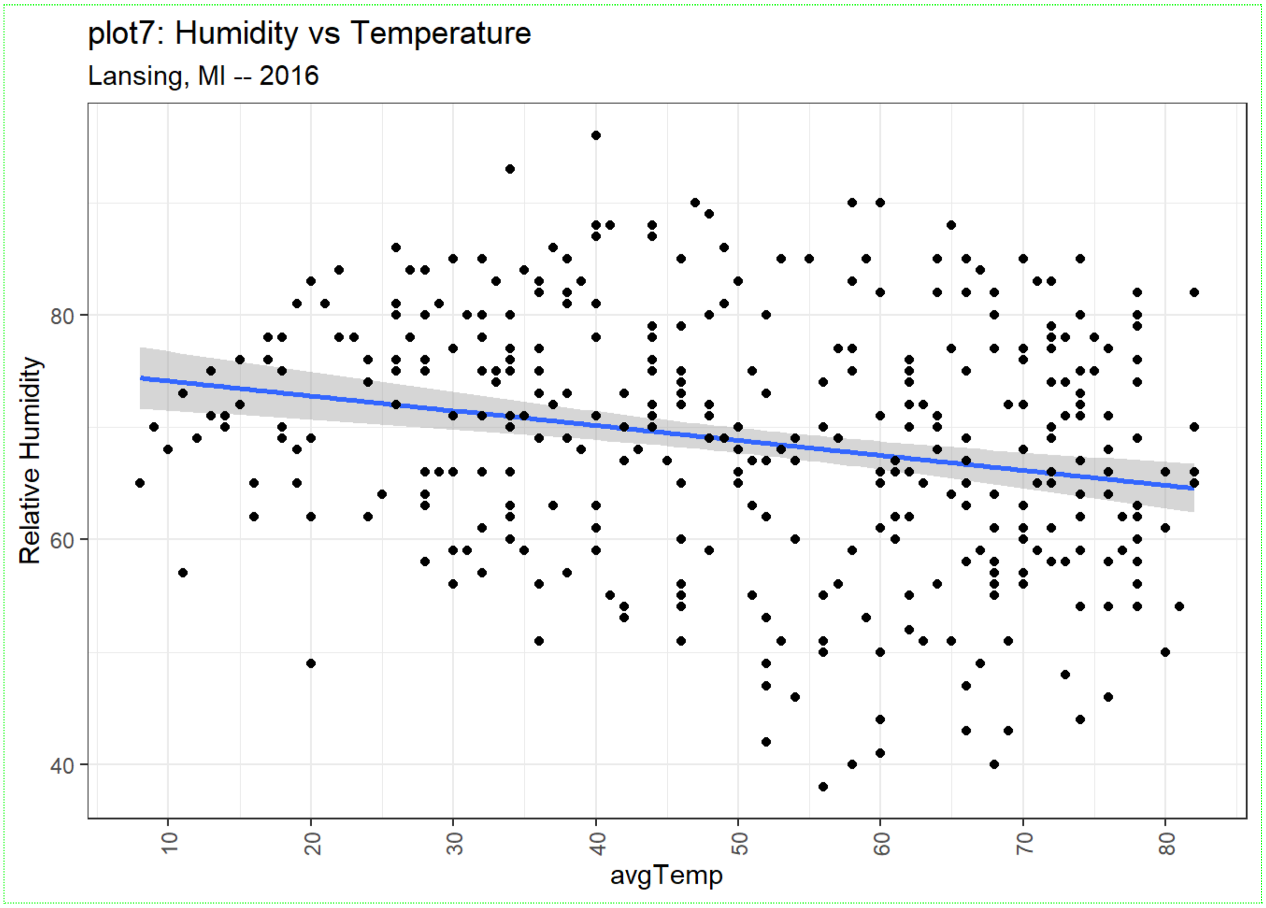


Figure 11: Switching the order of the components to change which plot is on top

9 Application

A) Create a script file names ***app2-01.r*** in your RStudio Project's ***scripts*** folder

B) Looking at the GGPlot cheat sheet (or the GGPlot functions page) from Section 3 answer the following in comments in ***app2-01.r***:

1. What component (function) would be used to create a text plot?
2. What component would you use to change the breaks on the x-axis if the values were in date format?

C) Create a scatterplot in GGPlot in your script:

1. Create a scatterplot of ***stnPressure*** vs ***windSpeed*** using the data from Lansing2016NOAA.csv
2. Add a title and labels the axes appropriately
3. Change the plot theme to one of your choice
4. Change the angle of the ***stnPressure*** axis labels to 45 degrees
5. Change the ***stnPressure*** breaks to go up by 0.1
6. Have the **wind-speed** axis only display three values: **3, 12, 21**
7. Add a linear regression of ***stnPressure*** vs ***windSpeed*** that appears behind the scatterplot
8. Challenge: Use the ***limits*** argument in ***scale_x_continuous*** and ***scale_y_continuous*** to remove the top and right parts of the plot where there are only a couple points.
    - ***limits*** is set equal to a vector with two values – so ***limits = c(0,100)*** would mean the axis would go from 0 to 100

Save the script as ***app2-01.r*** in your ***scripts*** folder and email your Project Folder to Charlie Belinsky at belinsky@msu.edu.

Instructions for zipping the Project Folder are here.

If you have any questions regarding this application, feel free to email them to Charlie Belinsky at belinsky@msu.edu.

9.1 Questions to answer

Answer the following in comments inside your application script:

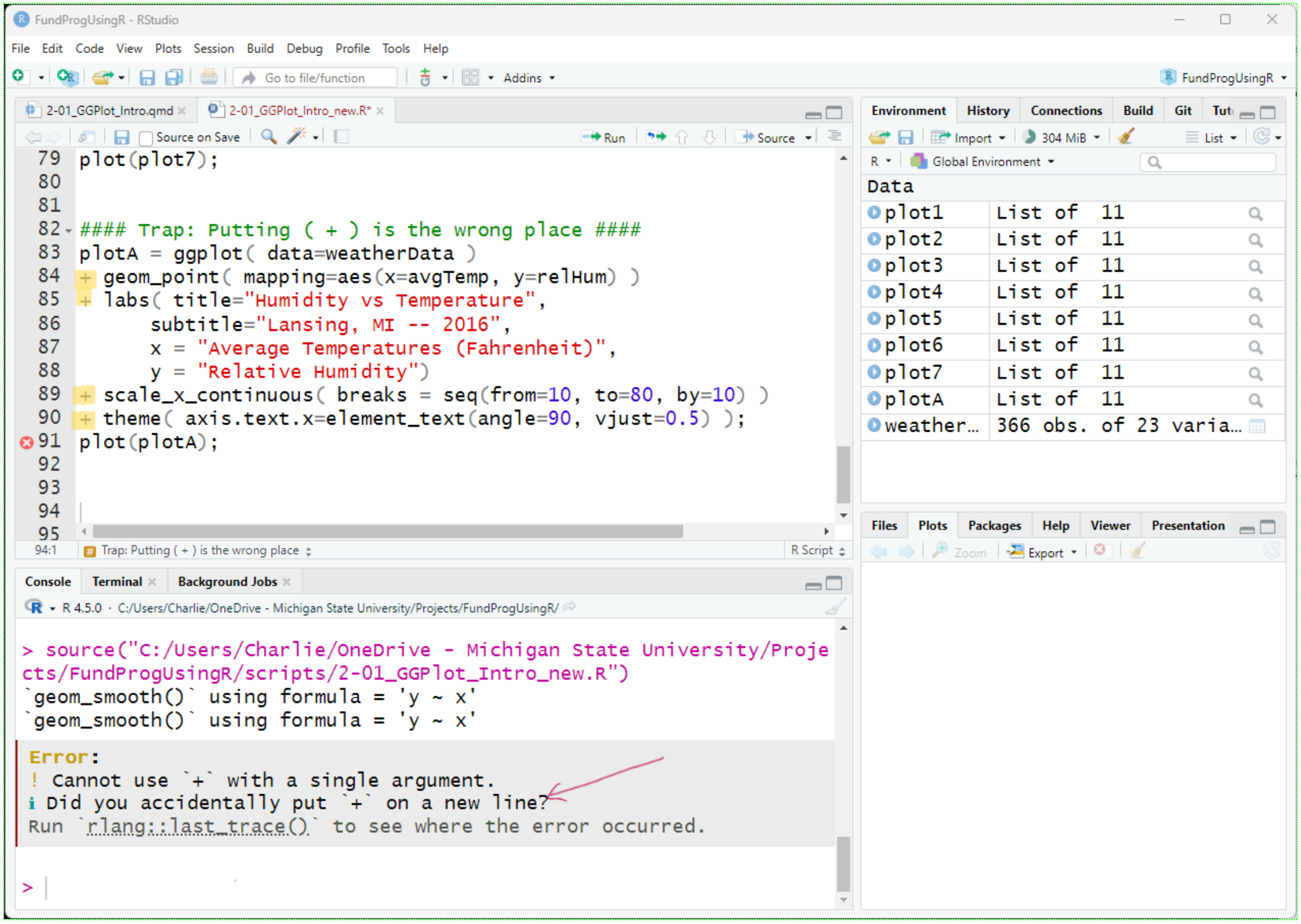
1. What was your level of comfort with the lesson/application?
2. What areas of the lesson/application confused or still confuses you?
3. What are some things you would like to know more about that is related to, but not covered in, this lesson?

10 Trap: Putting the (+) on the next line

The (**+**) commands strings together the components of a GGPlot. A common mistake is to put the (+) at the beginning of the following line:

```
#### Trap: Putting ( + ) is the wrong place ####
plotA = ggplot( data=weatherData )
+ geom_point( mapping=aes(x=avgTemp, y=relHum) )
+ labs( title="Humidity vs Temperature",
        subtitle="Lansing, MI -- 2016",
        x = "Average Temperatures (Fahrenheit)",
        y = "Relative Humidity")
+ scale_x_continuous( breaks = seq(from=10, to=80, by=10) )
+ theme( axis.text.x=element_text(angle=90, vjust=0.5) );
plot(plotA);
```

This will result in an error and a surprisingly wise assessment of the problem from the R debugger.


FundProgUsingR - RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
Go to file/function
Addins
FundProgUsingR
2-01_GGPlot_Intro.qmd
2-01_GGPlot_Intro_new.R*
Source on Save
Run
Source
Environment History Connections Build Git Tut
Import
304 MiB
List
R
Global Environment
Data
94:1
Trap: Putting (+) is the wrong place
R Script
Files Plots Packages Help Viewer Presentation
Zoom
Export
Console Terminal Background Jobs
R 4.5.0 · C:/Users/Charlie/OneDrive - Michigan State University/Projects/FundProgUsingR/

```
plot(plot7);


#### Trap: Putting ( + ) is the wrong place ####
plotA = ggplot( data=weatherData )
geom_point( mapping=aes(x=avgTemp, y=relHum) )
labs( title="Humidity vs Temperature",
      subtitle="Lansing, MI -- 2016",
      x = "Average Temperatures (Fahrenheit)",
      y = "Relative Humidity")
scale_x_continuous( breaks = seq(from=10, to=80, by=10) )
theme( axis.text.x=element_text(angle=90, vjust=0.5) );
plot(plotA);
```

plot1	List of 11
plot2	List of 11
plot3	List of 11
plot4	List of 11
plot5	List of 11
plot6	List of 11
plot7	List of 11
plotA	List of 11
weather…	366 obs. of 23 varia…

```
> source("C:/Users/Charlie/OneDrive - Michigan State University/Proje
cts/FundProgUsingR/scripts/2-01_GGPlot_Intro_new.R")
`geom_smooth()` using formula = 'y ~ x'
`geom_smooth()` using formula = 'y ~ x'

Error:
! Cannot use `+` with a single argument.
i Did you accidentally put `+` on a new line?
Run `rlang::last_trace()` to see where the error occurred.

>
```

Figure 12: Error when putting the (+) on the next line

The reason for this error is that R thinks this line:

```
plotA = ggplot( data=weatherData )
```

is a fully-formed and completed command

And R does not understand why the next line starts a new command with a (**+**)

```
+ geom_point( mapping=aes(x=avgTemp, y=relHum) )
```

A (**+**) at the end of a line tells R to append the next line to the current line. A (**+**) at the beginning of a line tells R to perform the mathematical operation addition.