Data Visualization

R for Stata Users

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Outline

Introduction

In this session, you'll learn how to use R to produce insightful, meaningful and (hopefully) nice-looking graphs. In particular, you'll use a package called `ggplot2`.

Similarly to the previous session, you can find some references at the end of this presentation that include a more comprehensive discussions on data visualization.

Introduction

Before we start, let's make sure we're all set:

1. Make sure you the packages `ggplot2` and `plotly` are installed and loaded.
2. Load the `whr_panel.csv` data set.

Introduction

```r
# Install packages
install.packages("plotly", # We already installed ggplot2
                 dependencies = TRUE)

# Load packages
library(ggplot2)
library(plotly)

#### Load CSV data

# Replace with where your data is
FolderPath <- file.path("YOUR/FOLDER/PATH")

whr <- read.csv(file.path(FolderPath,"whr_panel.csv"),
                header = T,
                stringsAsFactors = F)
```

Introduction

In our workflow there are usually two distinct uses for plots:

1. **Exploratory analysis:** Quickly visualize your data in an insightful way
   - We'll do this using R's base plot, that allows you to quickly create some basic plots
2. **Publication/Reporting:** Make pretty graphs for a presentation, a project report, or to just show your boss something other than the laziest graph you could come up with
   - We'll do this using `ggplot`, a flexible and powerful tool to plot beautiful graphs
   - `ggplot`'s syntax is more complicated, but it's easier to make your graphs look good with it

Outline

Exploratory graphs - Base plot

For exploratory plots, we're going to use Base plot. It is easy to use and can produce useful graphs with very few lines of code.

Exploratory graphs - Base plot

Exercise 1:

Plot the `whr_simp` data set you constructed in the previous session using the `plot()` function.

1. If you don't have the code from the previous session. Here it is:

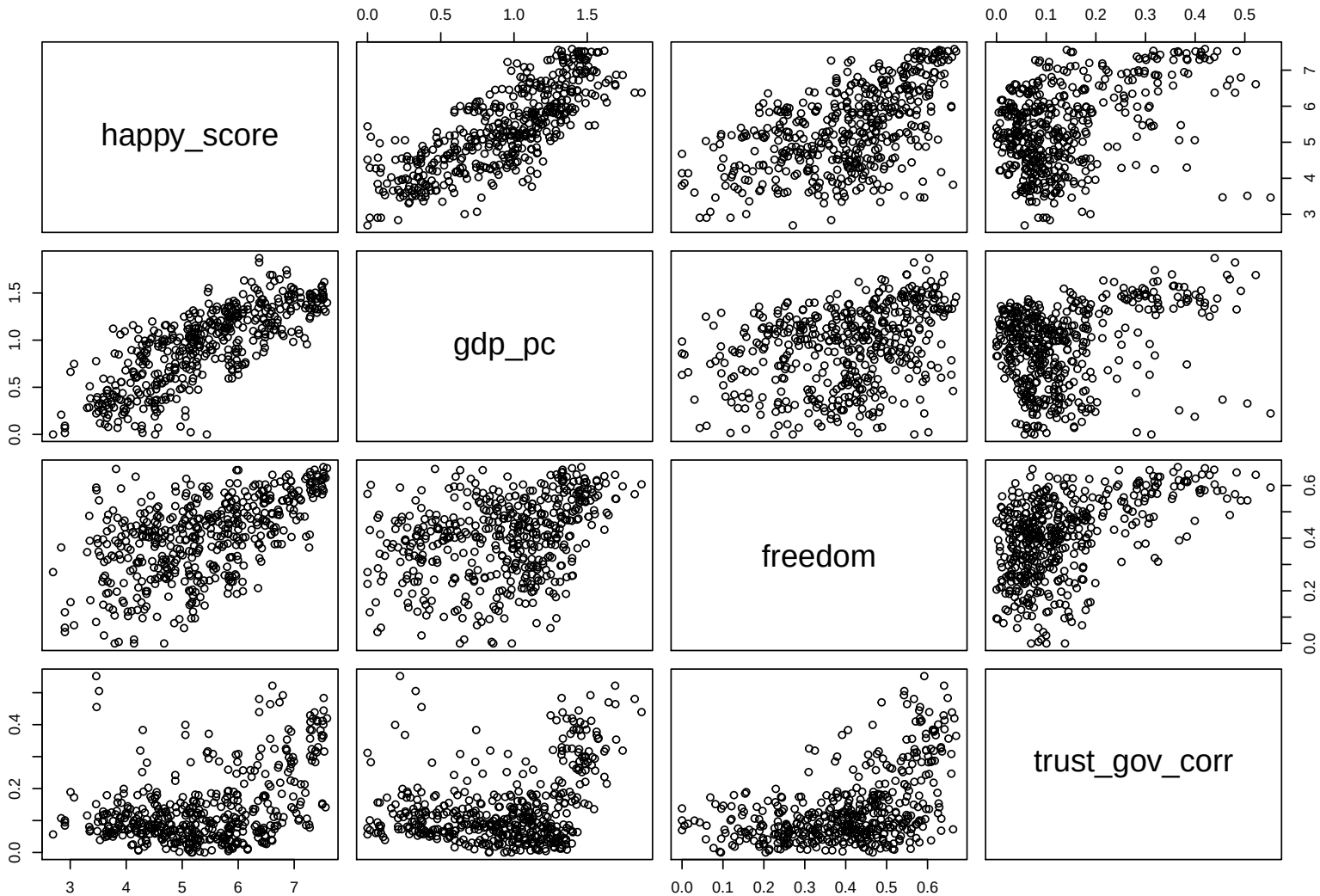
```
# Vector with covariates to be kept
covariates <- c("happy_score",
                "gdp_pc",
                "freedom",
                "trust_gov_corr")

# subset whr
whr_simp <- whr[, covariates]
```

2. Now, pass the name of the data set as the only argument for the plot function

Exploratory graphs - Base plot

```
plot(whr_simp)
```



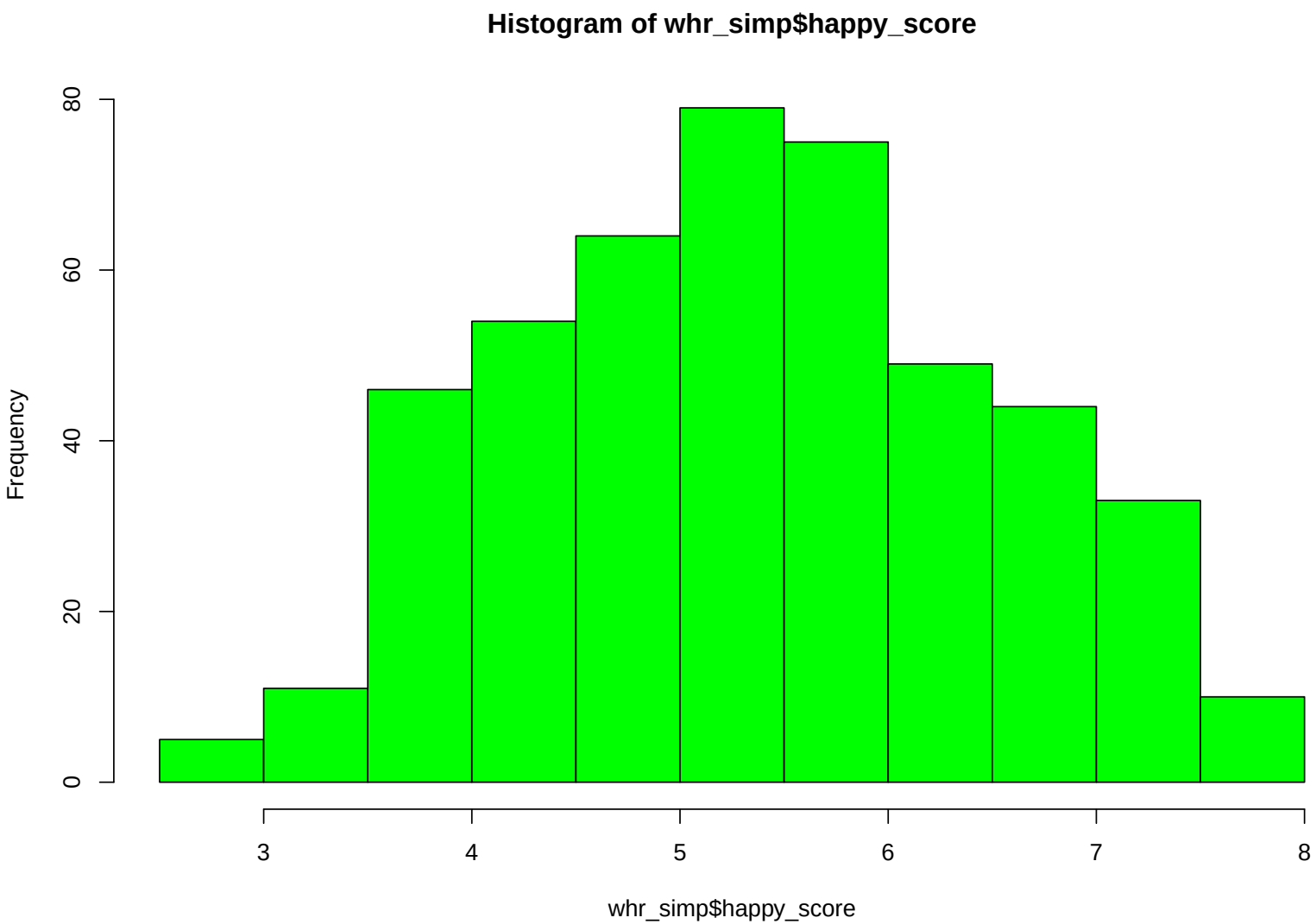
Exploratory graphs - Base plot

Exercise 2

1. Create a histogram of variable `happy_score` in data frame `whr_simp`. Use the `hist()` function for that.
2. Try to set the color as `"green"`. Use the help if you are not sure how to do it.

Exploratory graphs - Base plot

```
hist(whr_simp$happy_score, col = "green")
```



Exploratory graphs - Base plot

Exercise 3

Use the `boxplot()` function to see a description of the happiness score by region.

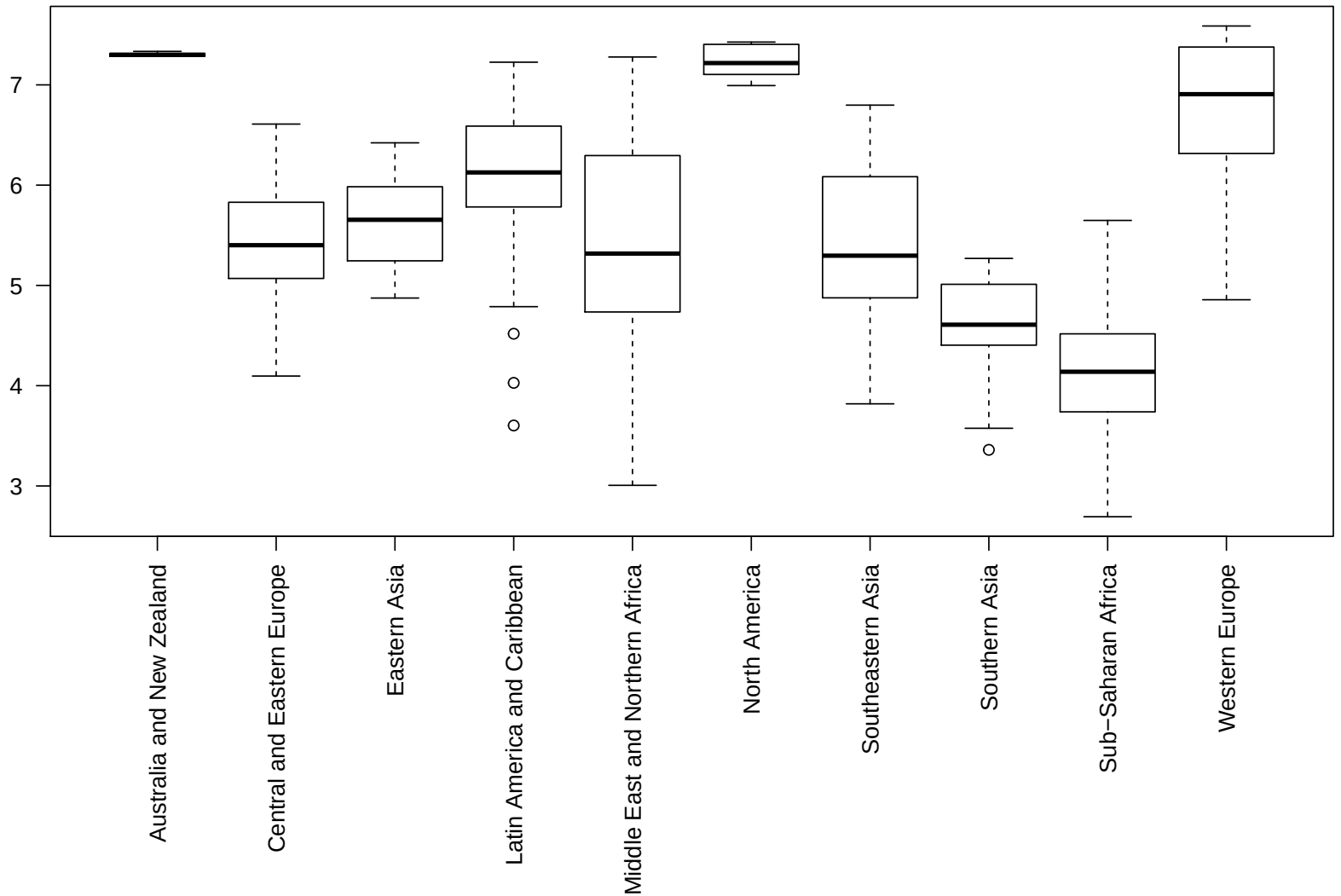
- TIP: The syntax for this function is `variable_to_be_plotted ~ variable_to_plot_over`.

Exploratory graphs - Base plot

Since these region labels are too long, I'm using an extra argument so we can actually read the x axis.

```
boxplot(whr$happy_score ~ whr$region, las = 2)
```

Exploratory graphs - Base plot



Outline

ggplot - Introduction

The ggplot2 package is an implementation of the theoretical framework for the construction of quantitative graphs developed in The Grammar of Graphics, a book by Leland Wilkinson.

It is a powerful and easy to use tool (once you understand its logic) that produces complex and multifaceted plots.

ggplot - Introduction

There are a few reasons why we use ggplot:

- It is generally easier to customize and tailor plots to your needs.
- It works great with almost any kind of plot, including maps, with little variation in syntax.
- It looks good.

ggplot - Grammar

Here is a list of ggplot2 most commonly used "grammar" elements:

Element	Description
Data	The dataset(s) being used.
Aesthetics	How your data is maped. For example what goes in the X and Y axis, size, shape and color.
Geometries	The visual elements used to represent the data (e.g. lines, dots, bars, etc.)
Themes	All non-data formating.

ggplot - Introduction

Exercise 4

First, let's create a very simple plot with the happiness score on the Y axis and afreedom on the X axis.

1. Use the `ggplot` function to store your plot in an object called `plot1`
   - Since it's the first one, Here's the code:

```
p1_happyfree <-
  ggplot(whr,
         aes(y = happy_score,
             x = freedom))
```

2. Now, try to print your plot. What happens?
   - You can do it by using the `print()` function or just typing the object name in the console

ggplot - Introduction

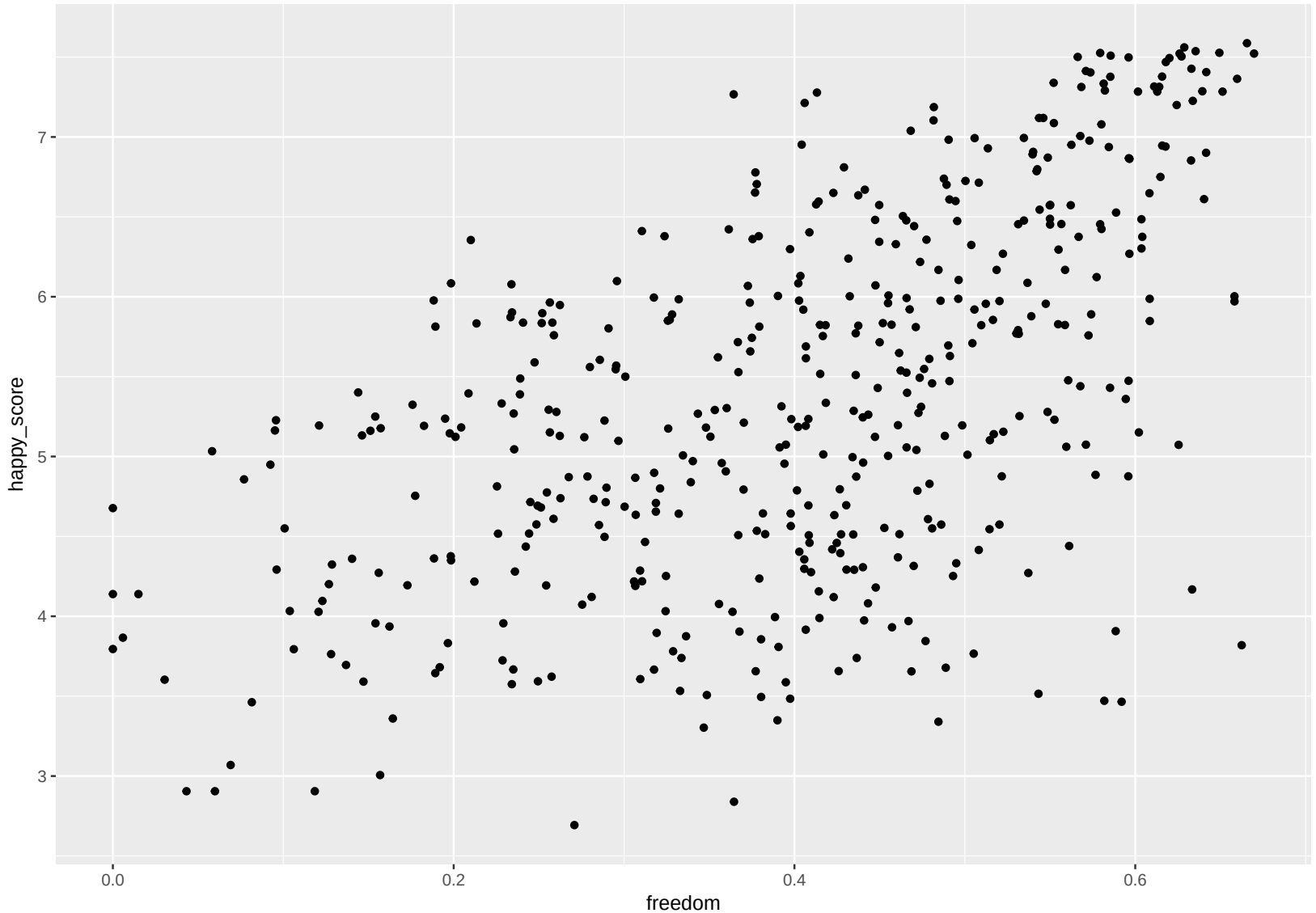
We mapped our variables, but without a geometry ggplot doesn't know how to represent the data.

Let's add a geometry

```
p1_happyfree <-
  ggplot(whr,
         aes(y = happy_score,
             x = freedom)) +
  geom_point()
```

ggplot - Introduction

```
print(p1_happyfree)
```



Outline

ggplot - Data structure

As almost everything in R, ggplot is very flexible and can be used in different ways. It is easier to work, however, if your data is in a specific format.

- Data has to be a data frame.
- Long format, especially categorical values.
  - It's better to have one variable with all the categories than a set of dummies.
- Labelled factors.

This is very similar to Stata, with the advantage of not needing to preserve and restore anything.

ggplot - Data structure

Here's an example of how an aggregated (collapsed) data set should look like:

```
##    year                          region happy_score
## 1  2015   Australia and New Zealand    7.285000
## 2  2016   Australia and New Zealand    7.323500
## 3  2017   Australia and New Zealand    7.299000
## 4  2015  Central and Eastern Europe    5.332931
## 5  2016  Central and Eastern Europe    5.370690
## 6  2017  Central and Eastern Europe    5.409931
## 7  2015                Eastern Asia    5.626167
## 8  2016                Eastern Asia    5.624167
## 9  2017                Eastern Asia    5.646667
## 10 2015 Latin America and Caribbean    6.144682
## 11 2016 Latin America and Caribbean    6.101750
```

ggplot - Data structure

- Since ggplot usually works better with data in a specific format, there are a few functions particularly useful to manipulate data
- Here, we'll use the aggregate() function
- aggregate() works similarly to collapse in Stata

ggplot - Data structure

To create a line plot with ggplot, we will create a new data set containing the average of happiness score by year.

```
# Aggregate annual income by year
annualHappy<-
  aggregate(happy_score ~ year,
            data = whr,
            FUN = mean)
```

Exercise 5

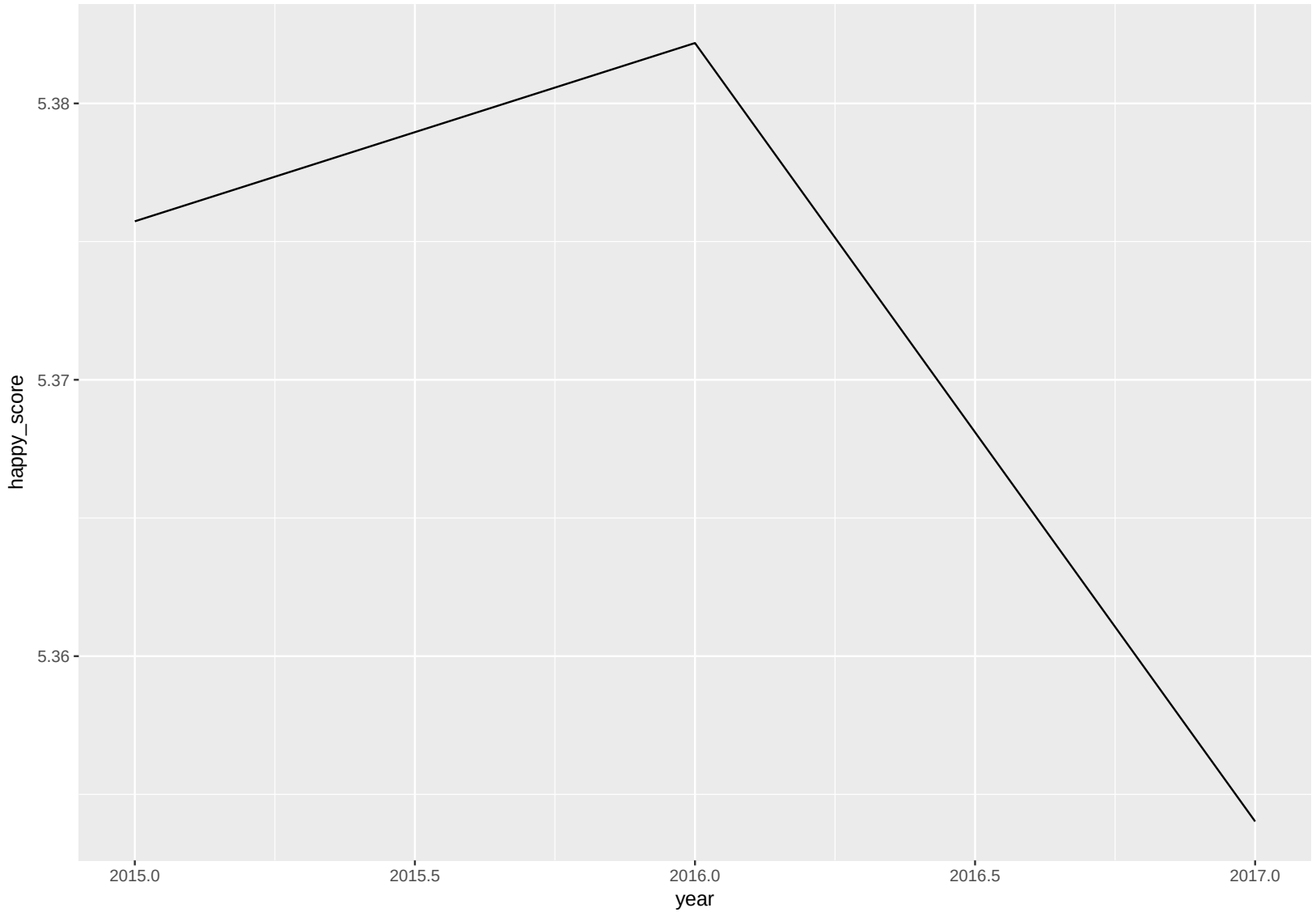
1. Use the `ggplot()` function with the `annualHappy` as the `data` argument, `happy_score` as `y` and `year` as `x` in `aes()`
2. This time, add `geom_line()`

ggplot - Data structure

```
# Plot code with arguments in geom
p2_happyyear <-
  ggplot(data = annualHappy,
         aes(y = happy_score,
             x = year)) +
  geom_line()
```

ggplot - Data structure

```
print(p2_happyyear)
```



ggplot - Data structure

Ok, it worked, but that was a really boring plot. Let's do a better one.

Exercise 6: Part 1

Use the `aggregate()` function to average happiness score, now, by two variables: `year` and `region`.

```
annualHappy_reg <-
  aggregate(happy_score ~ year + region,
            data = whr,
            FUN = mean)
```

ggplot - Data structure

```
# Aggregate data set
annualHappy_reg <-
  aggregate(happy_score ~ year + region,
            data = whr,
            FUN = mean)

annualHappy_reg[1:10,]
```

```
##    year                          region happy_score
## 1  2015   Australia and New Zealand    7.285000
## 2  2016   Australia and New Zealand    7.323500
## 3  2017   Australia and New Zealand    7.299000
## 4  2015  Central and Eastern Europe    5.332931
## 5  2016  Central and Eastern Europe    5.370690
## 6  2017  Central and Eastern Europe    5.409931
## 7  2015                Eastern Asia    5.626167
## 8  2016                Eastern Asia    5.624167
## 9  2017                Eastern Asia    5.646667
## 10 2015 Latin America and Caribbean    6.144682
```

ggplot - Data structure

Exercise 6: Part 2

Now, use ggplot as in the previous exercise to plot the aggregated data frame.

1. This time set the `color` and `group` arguments in the `aes()` function as the treatment variable.
2. Finally, add both line and point `geoms`.

ggplot - Data structure

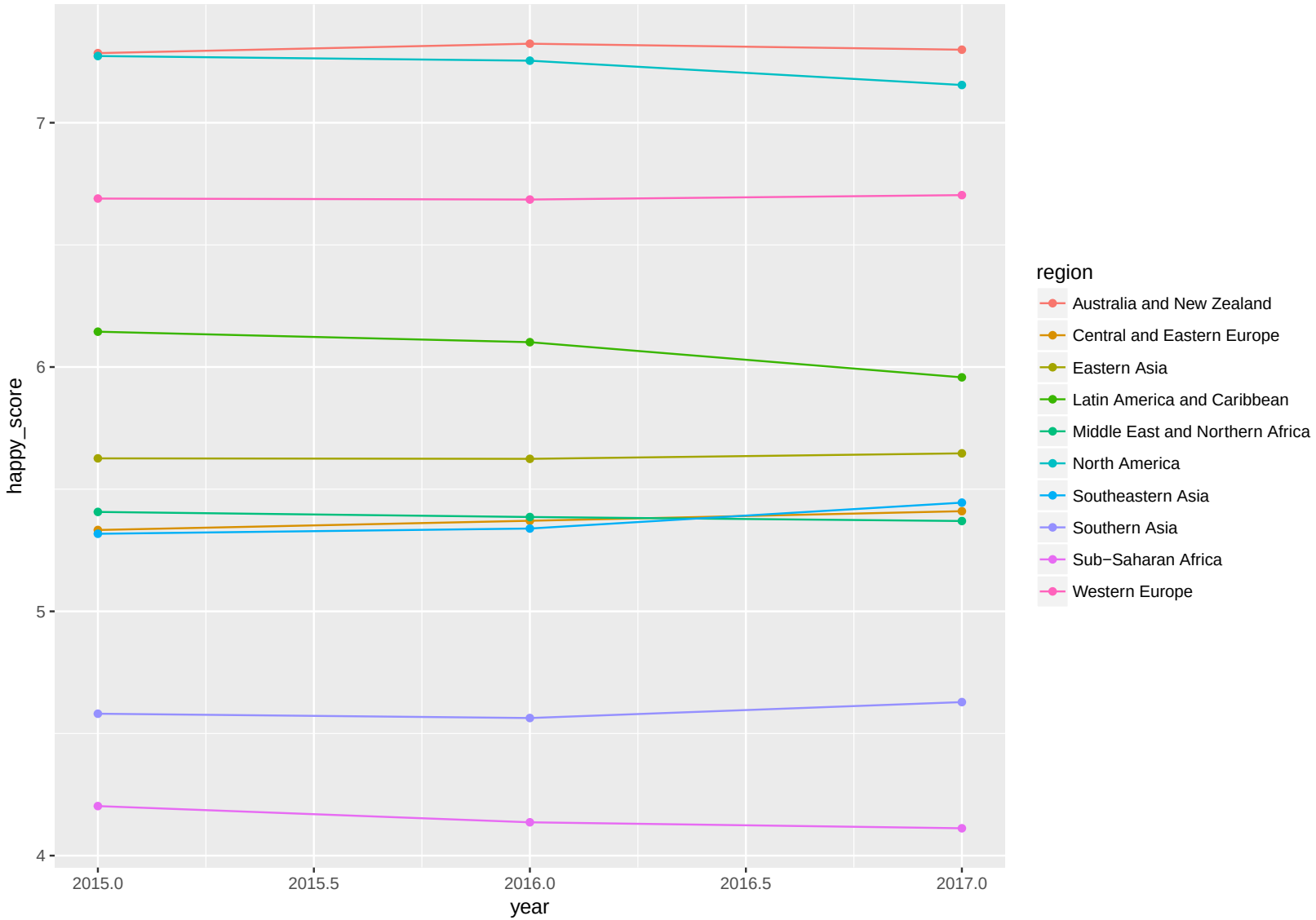
```r
# Aggregate data set
annualHappy_reg <-
  aggregate(happy_score ~ year + region,
            data = whr,
            FUN = mean)



# Plot aggregated data
p3_happyreg <-
  ggplot(data = annualHappy_reg,
         aes(y = happy_score,
             x = year,
             color = region,
             group = region)) +
    geom_line() +
    geom_point()

print(p3_happyreg)
```

ggplot - Data structure



ggplot - Data structure

You can also use ggplot to combine different data frames in the same plot.

- Everything inside the ggplot() function will be shared by all geometries added (e.g. the line and point geometries added to the previous exercise)
- But you can also pass different arguments to different geometries.

In the following example, to showcase just 3 regions, instead of restricting the data to only the interest regions, we are adding 3 separeate line geometries.

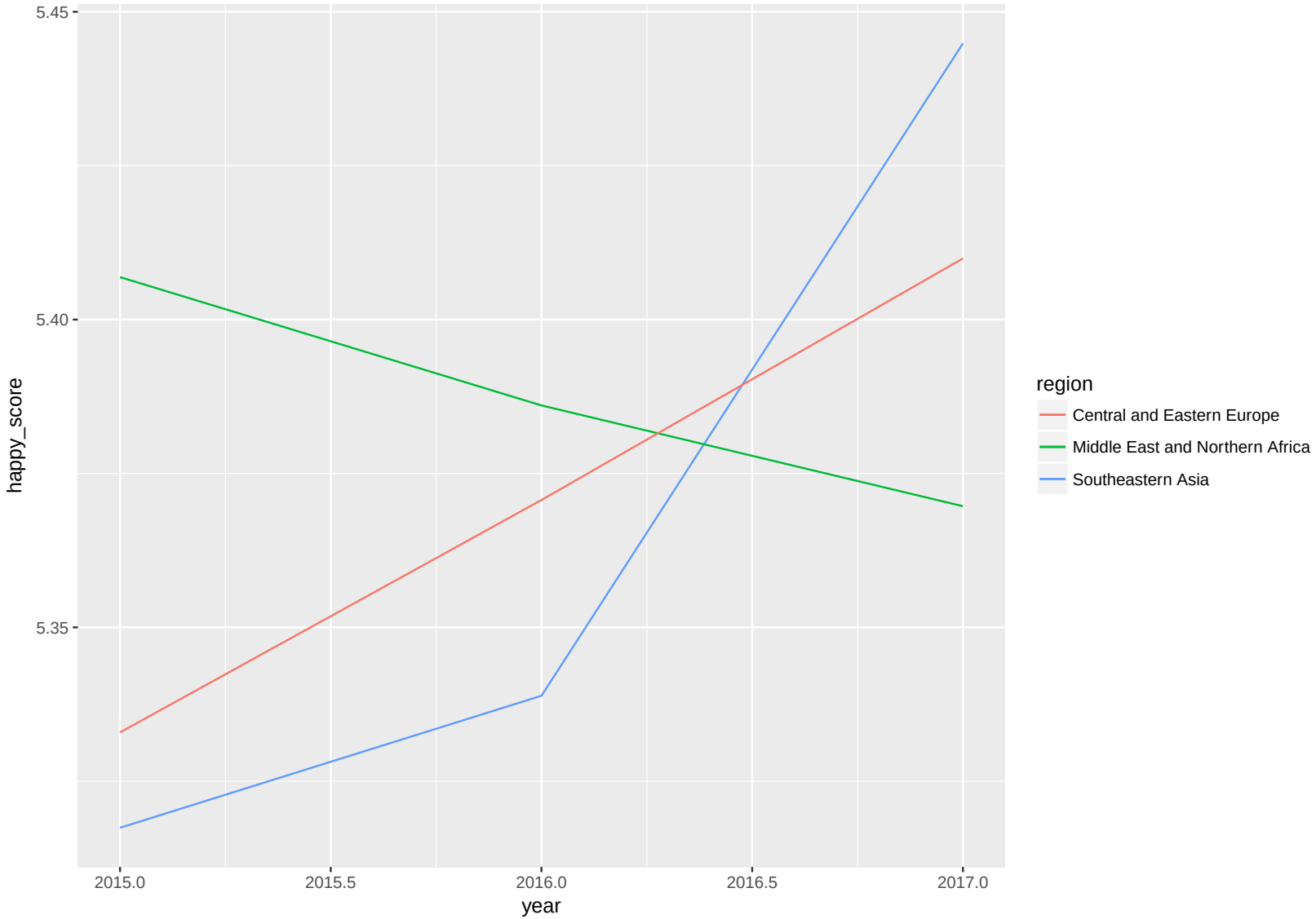
ggplot - Data structure

```r
# Separate datasets
sea <- annualHappy_reg[annualHappy_reg$region == "Southeastern Asia", ]
mena <- annualHappy_reg[annualHappy_reg$region == "Middle East and Northern Africa", ]
cee <- annualHappy_reg[annualHappy_reg$region == "Central and Eastern Europe", ]

# plot with 3 line geometries
p4_happy3reg <-
  ggplot() +
    geom_line(data = sea,  # Southeastern Asia
         aes(y = happy_score,
             x = year,
             color = region,
             group = region)) +
      geom_line(data = mena, # Middle East and Northern Africa
         aes(y = happy_score,
             x = year,
             color = region,
             group = region)) +
      geom_line(data = cee, # Central and Eastern Europe
         aes(y = happy_score,
             x = year,
             color = region,
             group = region))
```

ggplot and aggregate()

```
print(p4_happy3reg)
```



Outline

ggplot - Aesthetics

In ggplot , the aesthetic element defines how data is represented in the aesthetics (e.g. color, shape and size) of geometric objects (e.g. points, lines and bars).

Exercise 7: Part 1

1. Create a data frame containing only 2017 observations of `whr`.

   - TIP: This time we want to keep only observations (lines) that meet a certain condition. Use the left argument of the brackets operators. Like this:

```
whr[CONDITION,]
```

2. Use `ggplot()` to scatter happiness score and freedom.

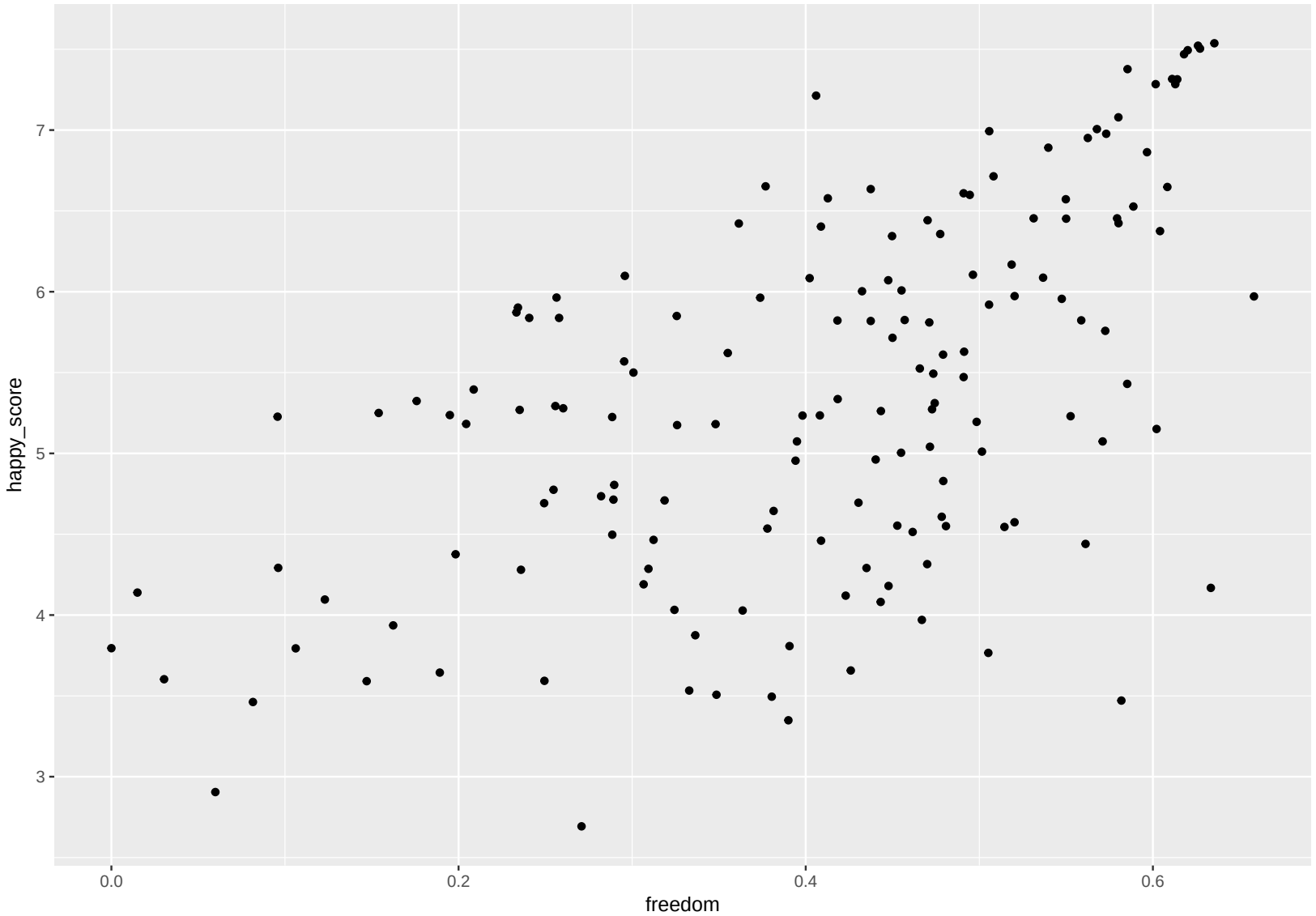
ggplot - Aesthetics

```
# Subset whr to 2017
whr17 <- whr[whr$year == 2017, ]

# Plot
p5_happyfree17 <-
  ggplot(whr17, aes(x = freedom,
                    y = happy_score)) +
      geom_point()
```

ggplot - Aesthetics

```
print(p5_happyfree17)
```



ggplot - Aesthetics

Now add the region to `aes()`.

Exercise 7: Part 2

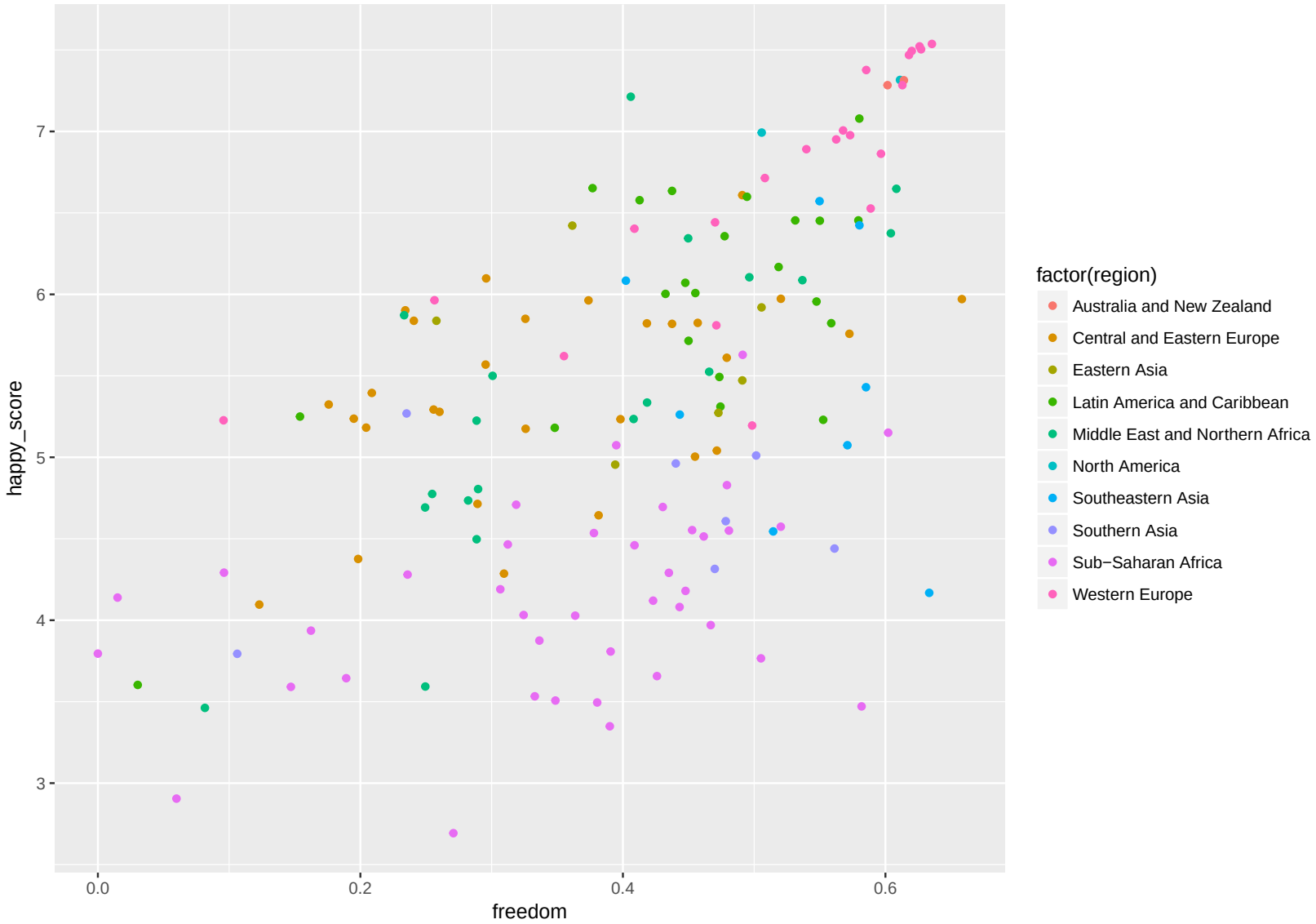
1. Use the `region` variable as color in `aes()`.
   - TIP: this is is a categorical variable, but it is stored in string format. Use the `factor()` function. Like this:

```
color = factor(region)
```

ggplot - Aesthetics

```
# Plot code
p6_happyfree17reg <-
  ggplot(whr17,
         aes(x = freedom,
             y = happy_score)) +
  geom_point(aes(color = factor(region)))
```

ggplot - Aesthetics



ggplot - Aesthetics

Now we will combine different arguments of `aes()`

Exercise 7: Part 3

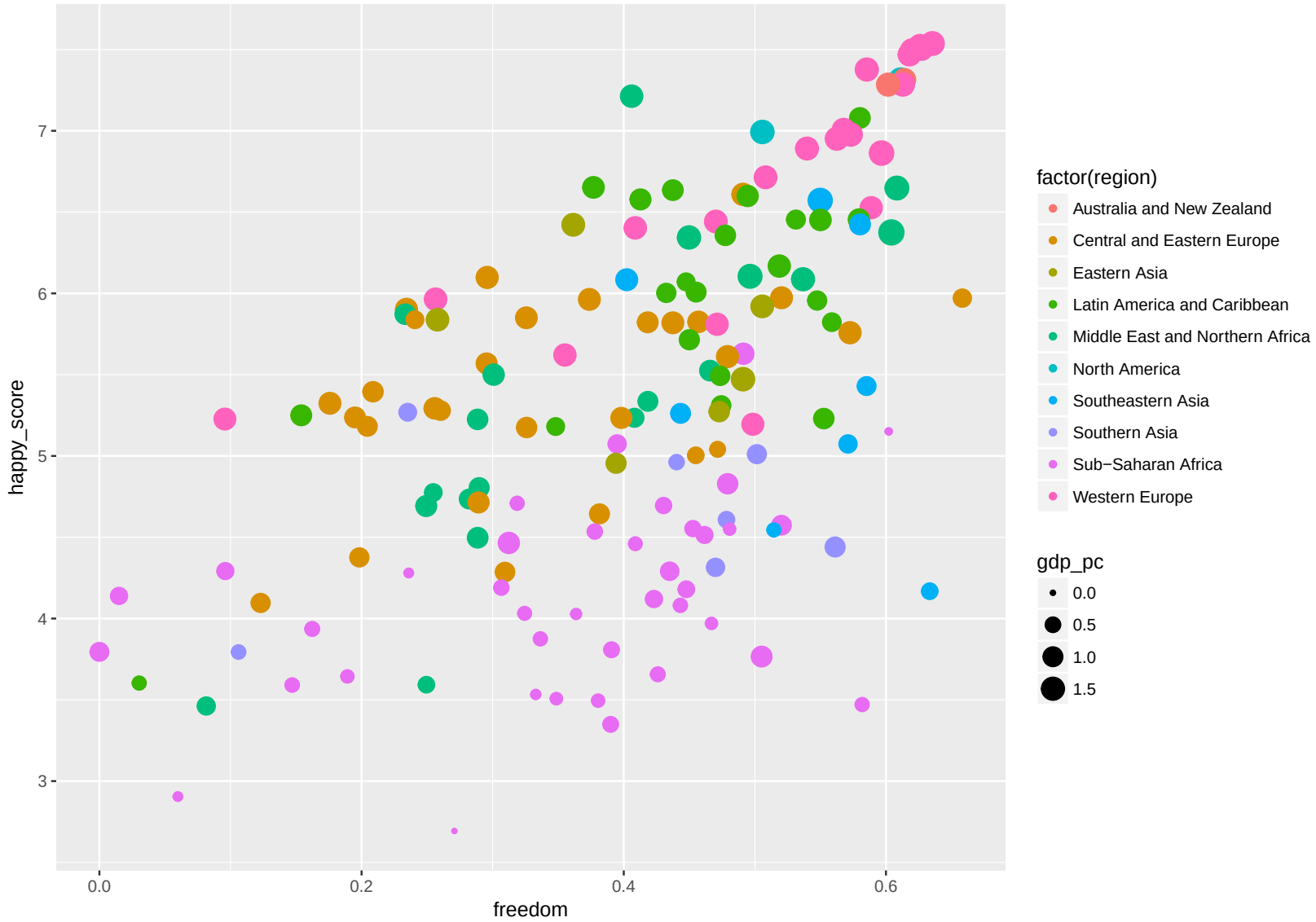
1. Add `gdp_pc` to the `size` argument of `aes()` in your last graph.

ggplot - Aesthetics

```
# Plot code
p6_happyfree17reg <-
  ggplot(whr17,
         aes(x = freedom,
             y = happy_score)) +
  geom_point(aes(color = factor(region),
                 size = gdp_pc))
```

ggplot - Aesthetics

```
print(p6_happyfree17reg)
```

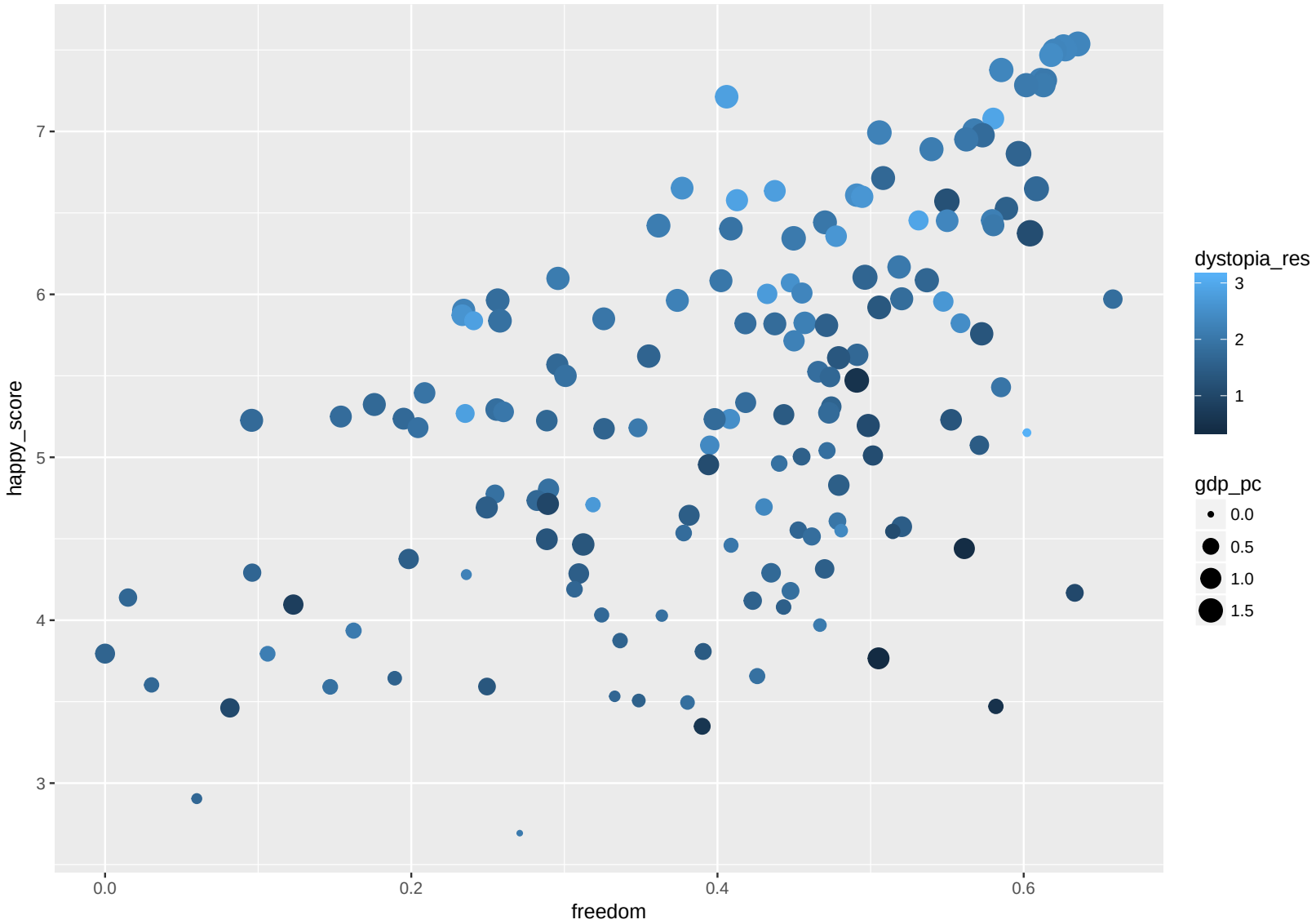


ggplot - Aesthetics

- Because we used a factor variable as the color in the aesthetic, it displayed different categories clearly
- If we had used a numeric variable instead, it would have created a gradient
- You'll not create this for time's sake, but here's how it would look:

```
# Plot code
ggplot(whr17, aes(x = freedom,
                  y = happy_score,
                  color = dystopia_res,
                  size = gdp_pc)) +
    geom_point()
```

ggplot - Aesthetics



Outline

ggplot - Titles and labels

Lastly, we can add titles, axis labels and format legends. This is done by adding additional layers to the plot.

To add a title and legend to the X and Y axis, we use the functions listed below. They all take a string scalar as argument.

- `ggtitle()` - adds a title to the plot
- `xlab()` - adds a label to X axis
- `ylab()` - adds a label to Y axis

ggplot - Titles and labels

To add legend titles, we will use two functions that control the formatting of the aesthetic. As they can take many different arguments, we use `name` argument sets legend title:

- `scale_color_discrete()` - formatting of the color aesthetic.
- `scale_size_continuous()` - formatting of the color aesthetic.

ggplot - Titles and labels

Exercise 8

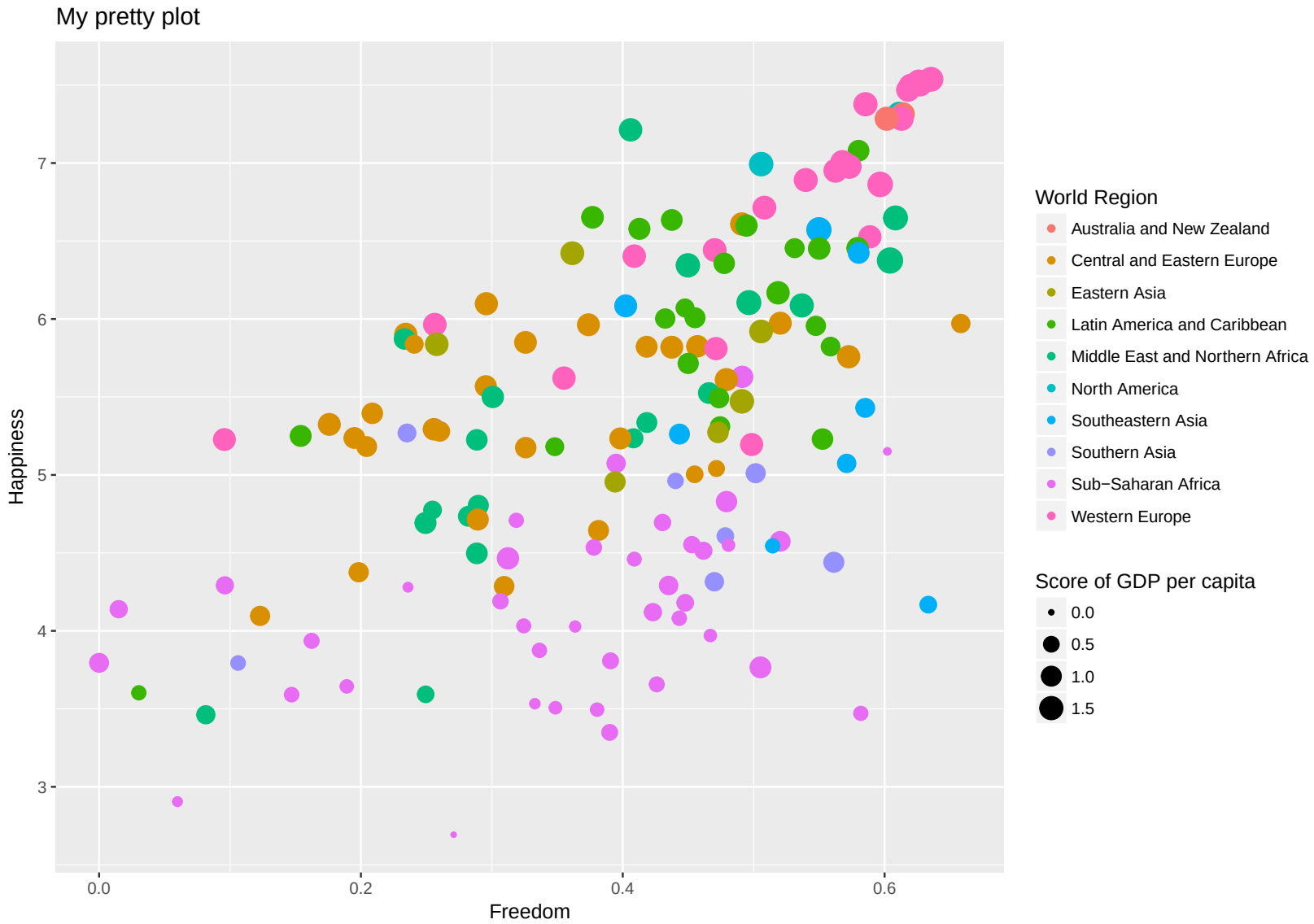
1. Copy the code for the graph produced in the previous exercise.
2. Use the + symbol to add the layer.
3. `ggtitle()`, `xlab()` and `ylab()` take simple strings as inputs.
4. For `scale_color_continuous()` and `scale_size_continuous()` you need to specify `name` argument as the desired string.

ggplot - Titles and labels

```
# A properly labelled plot
p6_happyfree17reg <-
  p6_happyfree17reg +
      ggtitle("My pretty plot") +
      xlab("Freedom") +
      ylab("Happiness") +
      scale_color_discrete(name = "World Region") +
      scale_size_continuous(name = "Score of GDP per capita")
```

ggplot - Titles and labels

```
print(p6_happyfree17reg)
```



Outline

Saving a plot

Let's save the previous plot using the PDF graphics device

Exercise 9:

1. Open the PDF graphics device by using the `pdf()` function.
2. Set the `file` argument as your outputs path with the file name (including ".pdf")
3. Paste the code of the previous plot bellow the `pdf()` function.
4. Finally, use the `dev.off()` to close the device, i.e. tell R that you're finished plotting.

Saving a plot

```
 Output <- "YOUR/PATH/HERE"

# Open PDF graphics device
 pdf(file = file.path(Output, "plot1.pdf"))

  # Plot
  print(p6_happyfree17reg)

# Close PDF graphics device
dev.off()
```

Outline

Interactive graphs

There are several packages to create interactive or dynamic data vizualizations with R. Here are a few:

- `leaflet` - R integration tp one of the most popular open-source libraries for interactive maps.
- `highcharter` - cool interactive graphs.
- `plotly` - interactive graphs with integration to ggplot.
- `gganimate` - ggplot GIFs.
- `DT` - Interactive table

These are generally, html widgets that can be incorporated in to an html document and websites.

Interactive graphs

Now we'll use the `ggplotly()` function from the `plotly` package to create an interactive graph!

Exercise 9

1. Load the `plotly` package
2. Pass that object with the last plot you created to the `ggplotly()` function

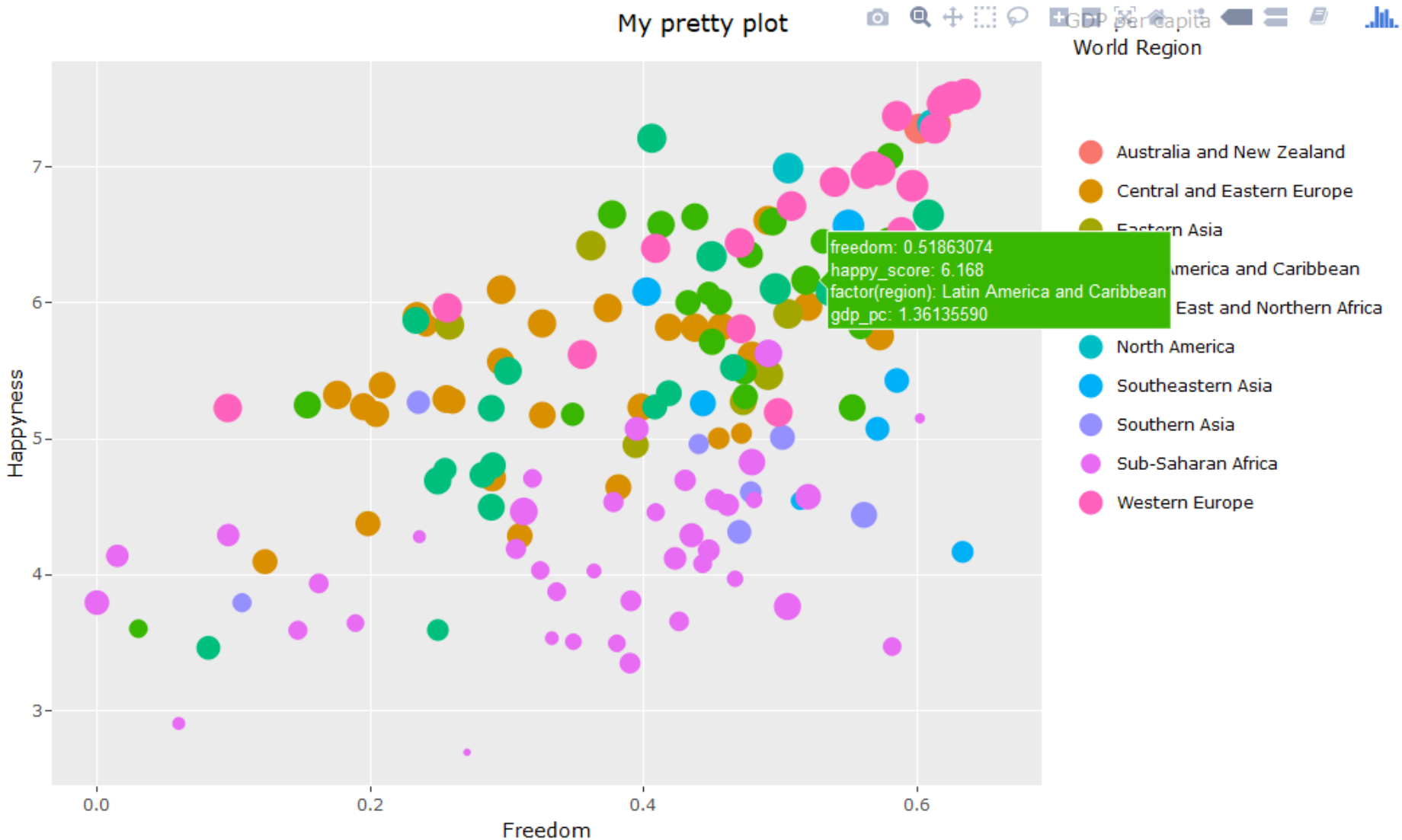
Interactive graphs

```
# Load package
library(plotly)

 # Use ggplotly to create an interactive plot
 ggplotly(p6_happyfree17reg)
```

Interactive graphs

(Sorry, this is a .pdf presentation so this is just a screenshot.)



Homework - Interactive graphs

We can add pop-up information by adding another argument to the `aes()` function.

Customize your ggplotly plot

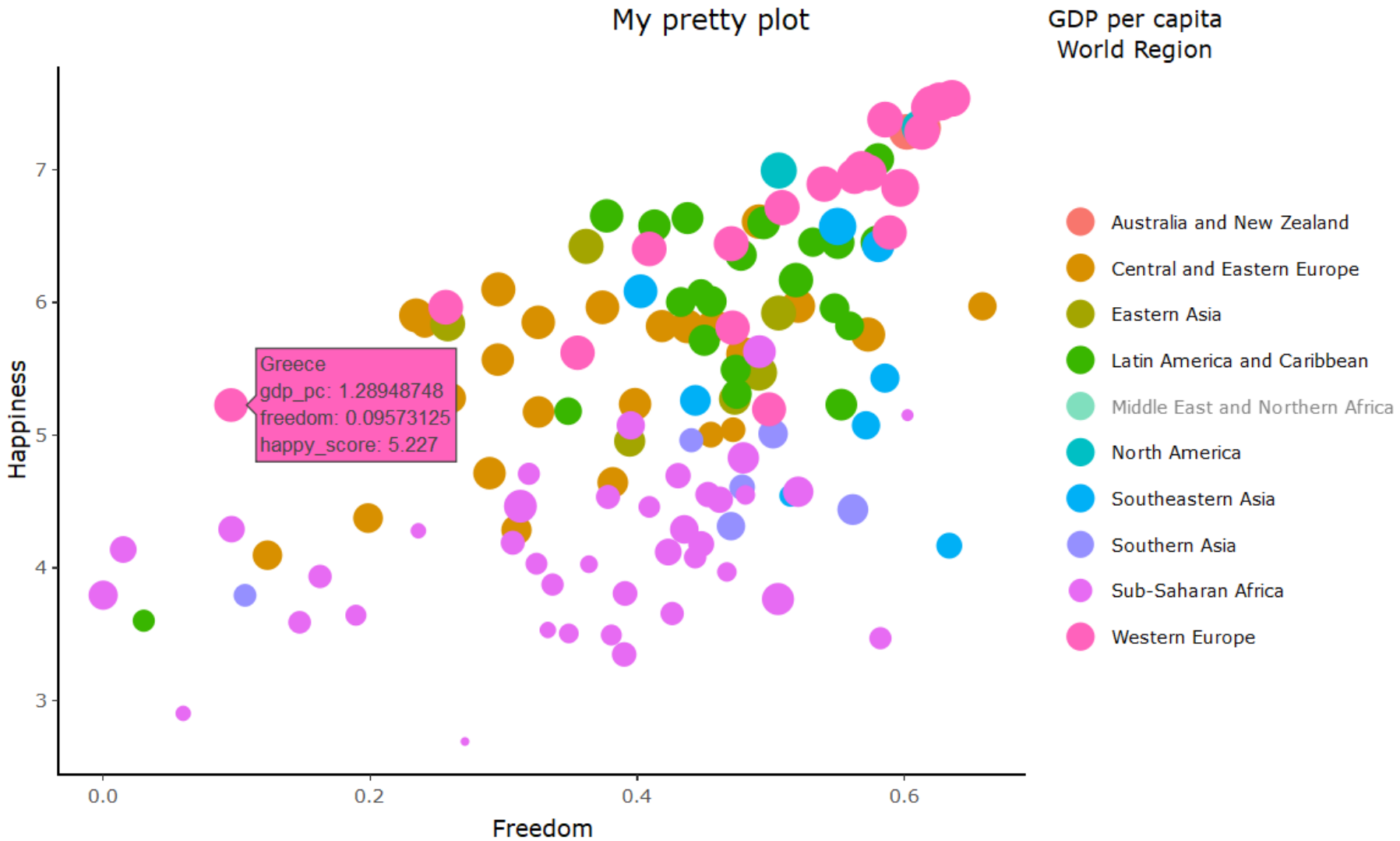
1. Add a `text` argument to the`geom_point` `aes()` function and assign it to the `country` variable. This argument won't be recognized by `ggplot()`, but will be by `ggplotly()`.
2. Use themes to change the background color. You can find a list of default themes in https://ggplot2.tidyverse.org/reference/ggtheme.html

   - TIP: type `?ggthemes::` on the console for more options

3. Use the `tooltip` argument of the `ggplotly` function to customize what is shown when hovering

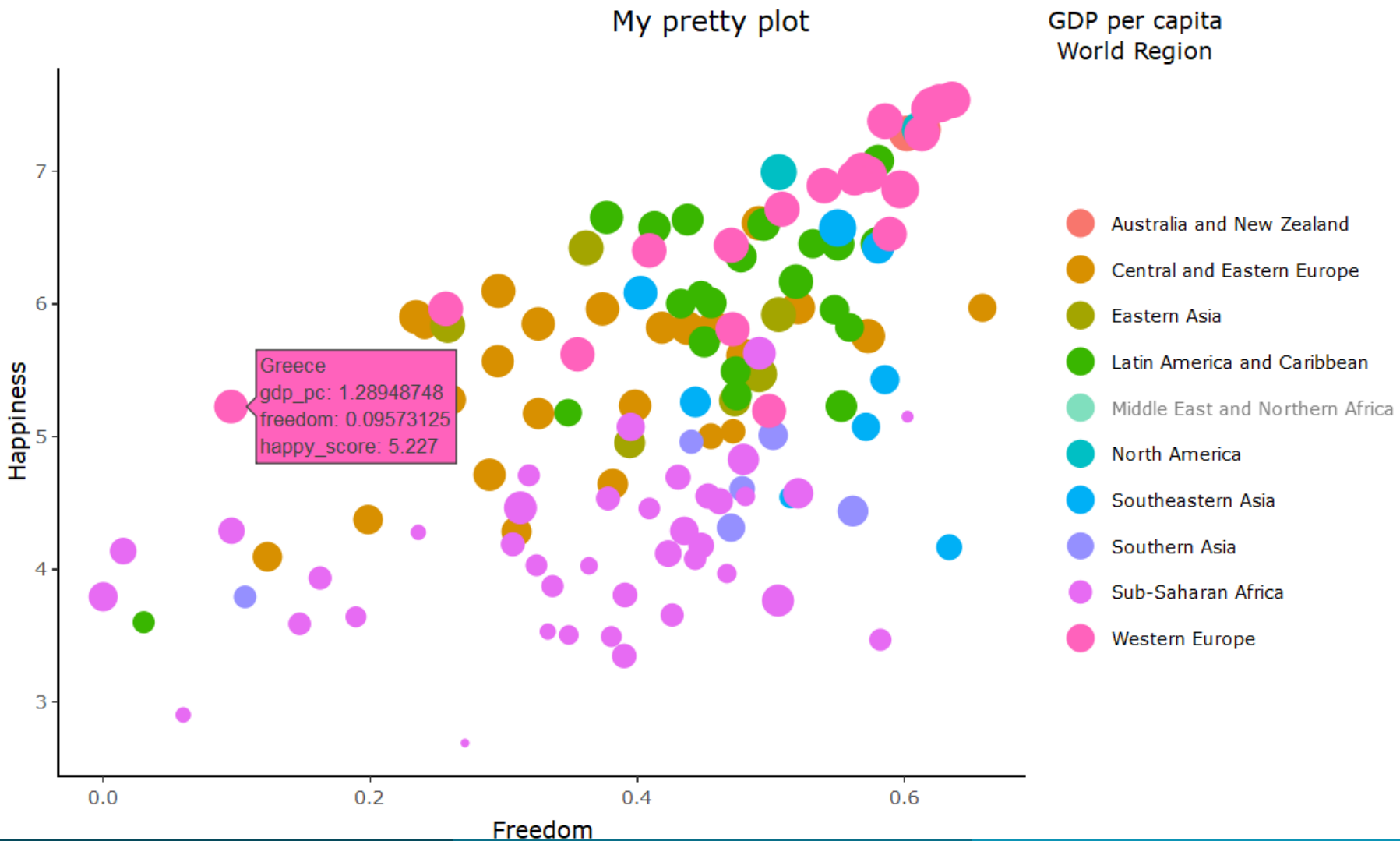
Interactive graphs

Here's what we've done:



Interactive graphs

(Sorry, this is a .pdf presentation so this is just a screenshot.)



Outline

References and recommendations

Websites:

- Interactive stuff : http://www.htmlwidgets.org/
- The R Graph Gallery: https://www.r-graph-gallery.com/
- Gpplot official site: http://ggplot2.tidyverse.org/

Online courses:

- Johns Hopkins Exploratory Data Analysis at Coursera: https://www.coursera.org/learn/exploratory-data-analysis

Books:

- The grammar of graphics by Leland Wilkinson.
- Beautiful Evidence by Edward Tufte.
- R Graphics cook book by Winston Chang
- R for Data Science by Hadley Wickham andGarrett Grolemund

Outline

R common graphic devices

R has several built-in graphic devices. A graphic device is the medium where you visually represent a plot. Here are the most come:

- The standard screen device or the plot pane in RStudio.
- PDF file (file device).
- PNG (file device).
- JPEG (file device).

Differed ways of saving a plot

There are a couple of ways of saving plots in R:

- With ggplot you can use the `ggsave()` function that has a simple syntax and can do most of the dirty work for you.
- Choosing an specific graphics device (other than the default window). pdf(), png(), jpeg() and bmp() are functions that call graphic devices that save your plots in these formats. There are a few others built-in and you can check them by typing *?Devices*, and even more in CRAN.

Graphic systems

R has four main graphic systems:

- Base plot - most basic plotting system.
- Grid graphics - is a low-level graphics system mainly used by package developers.
- Lattice graphics - easy way to plot high dimensional data or many graphs at the same time.
- Ggplot2 - a flexible and powerful tool to plot beautiful graphs with intuitive syntax