Session 4: Data Visualization

R for Stata Users

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Introduction

Introduction

Initial Setup

If You Attended Session 2   If You Did Not Attend Session 2

1. Go to the `dime-r-training-main` folder that you created yesterday, and open the `dime-r-training-main` R project that you created there.

Introduction

Initial Setup

If You Attended Session 2   **If You Did Not Attend Session 2**

1. Copy/paste the following code into a new RStudio script, **replacing "YOURFOLDERPATHHERE" with the folder within which you'll place this R project:

```
library(usethis)
use_course(
    url = "https://github.com/worldbank/dime-r-training/archive/main.zip",
    destdir = "YOURFOLDERPATHHERE"
)
```

1. In the console, type in the requisite number to delete the .zip file (we don't need it anymore).

2. A new RStudio environment will open. Use this for the session today.

Today's session

Exploratory Analysis v. Publication/Reporting

Data, aesthetics, & the grammar of graphics

Aesthetics in extra dimensions, themes, and saving plots

For this session, you'll use the `ggplot2` package from the `tidyverse` meta-package.

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

Introduction

Before we start

- Make sure the packages `ggplot2` are installed and loaded. You can load it directly using `library(tidyverse)` or `library(ggplot2)`
- Load the `whr_panel` data set (remember to use the `here` package) we created last week.

```
# Packages
library(tidyverse)
library(here)

whr_panel <- read_csv(
  here(
    "DataWork", "DataSets", "Final", "whr_panel.csv"
  )
)
```

```
## Rows: 470 Columns: 8
## — Column specification ──────────────────────────
## Delimiter: ","
## chr (2): country, region
## dbl (6): year, happiness_rank, happiness_score, economy_gdp_per_capita, heal...
```

Introduction

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

1. **Exploratory analysis**: Quickly visualize your data in an insightful way.

   - Base R can be used to quickly create basic figures
   - We will also use `ggplot2` to quickly create basic figures as well.

2. **Publication/Reporting**: Make pretty graphs for a presentation, a project report, or papers:

   - We'll do this using `ggplot2` with more customization. The idea is to create beautiful graphs.

Exploratory Analysis

Plot with Base R

First, we're going to use base plot, i.e., using Base R default libraries. It is easy to use and can produce useful graphs with very few lines of code.
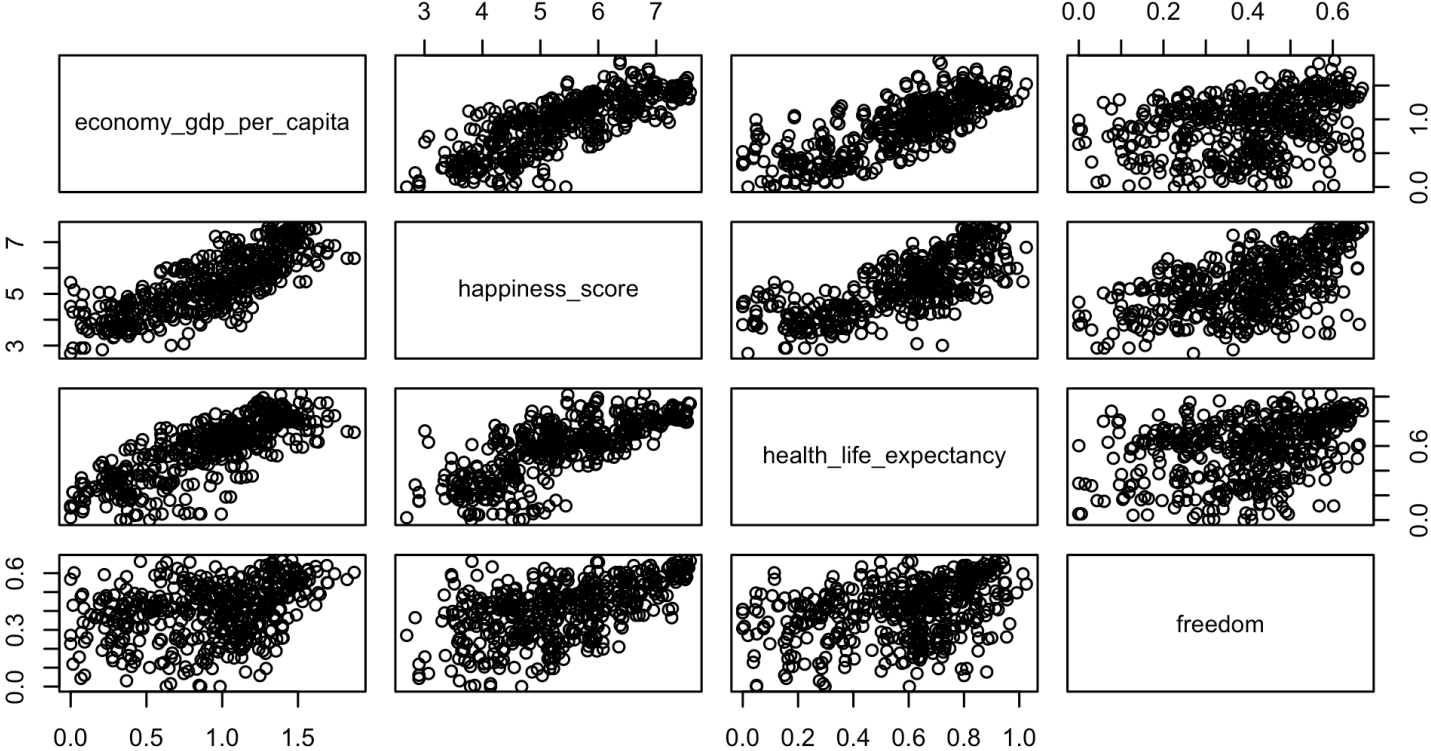
> **Exercise 1:** Exploratory Analysis.
>
> **(1)** Create a vector called `vars` with the strings: `"economy_gdp_per_capita"`, `"happiness_score"`, `"health_life_expectancy"`, and `"freedom"`.
> **(2)** Select all the variables from the vector `vars` in the `whr_panel` dataset and assign to the object `whr_plot`. Hint: use `select(all_of(vars))` for this.
> **(3)** Use the `plot()` function: `plot(whr_plot)`

```r
# Vector of variables
vars <- c("economy_gdp_per_capita", "happiness_score", "health_life_expectancy", "freedom")
# Create a subset with only those variables, let's call this subset whr_plot
whr_plot <- whr_panel %>%
  select(all_of(vars))
```

`01:00`

Base Plot

The beauty of ggplot2

1. Consistency with the **Grammar of Graphics**
   - This book is the foundation of several data viz applications: `ggplot2`, `polaris-tableau`, `vega-lite`
2. Flexibility
3. Layering and theme customization
4. Community

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

ggplot2: basic structure (template)

The basic ggplot structure is:

```
ggplot(data = DATA) +
  GEOM_FUNCTION(mapping = aes(AESTHETIC MAPPINGS))
```

Mapping data to aesthetics

Think about colors, sizes, x and y references

We are going to learn how we connect our data to the components of a ggplot

ggplot2: full structure

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(
    mapping = aes(<MAPPINGS>),
    stat = <STAT>,
    position = <POSITION>
  ) +z
  <COORDINATE_FUNCTION> +
  <FACET_FUNCTION> +
  <SCALE_FUNTION> +
  <THEME_FUNCTION>
```

1. `Data` : The data that you want to visualize
2. `Layers` : geom_ and stat_ → The geometric shapes and statistical summaries representing the data
3. `Aesthetics` : aes() → Aesthetic mappings of the geometric and statistical objects
4. `Scales` : scale_ → Maps between the data and the aesthetic dimensions
5. `Coordinate system` : coord_ → Maps data into the plane of the data rectangle
6. `Facets` : facet_ → The arrangement of the data into a grid of plots
7. `Visual themes` : theme() and theme_ → The overall visual defaults of a plot

ggplot2: decomposition

There are multiple ways to structure plots with ggplot

For this presentation, I will stick to Thomas Lin Pedersen's decomposition who is one of most prominent developers of the ggplot and gganimate package.
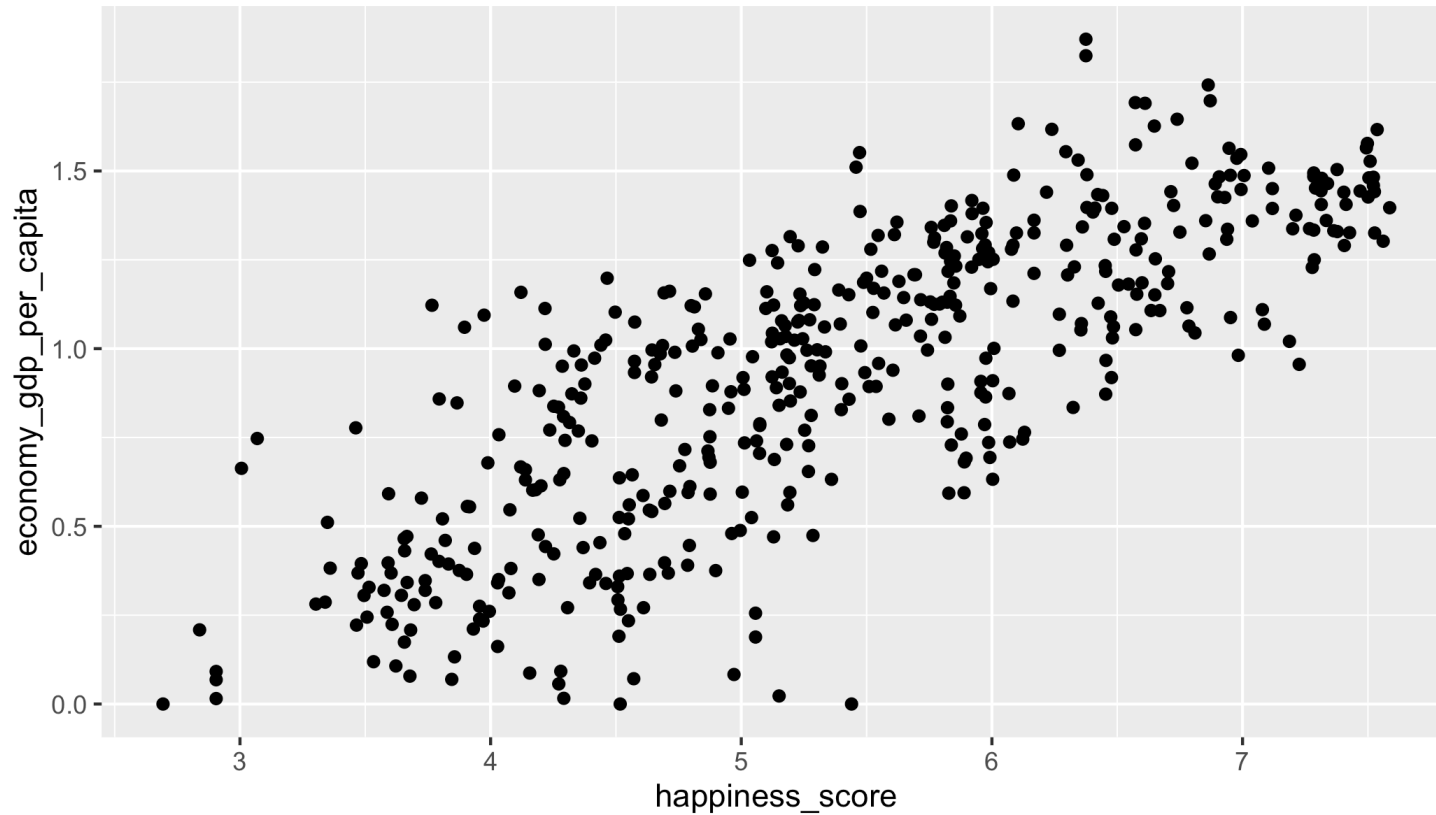
These components can be seen as layers, this is why we use the + sign in our ggplot syntax.

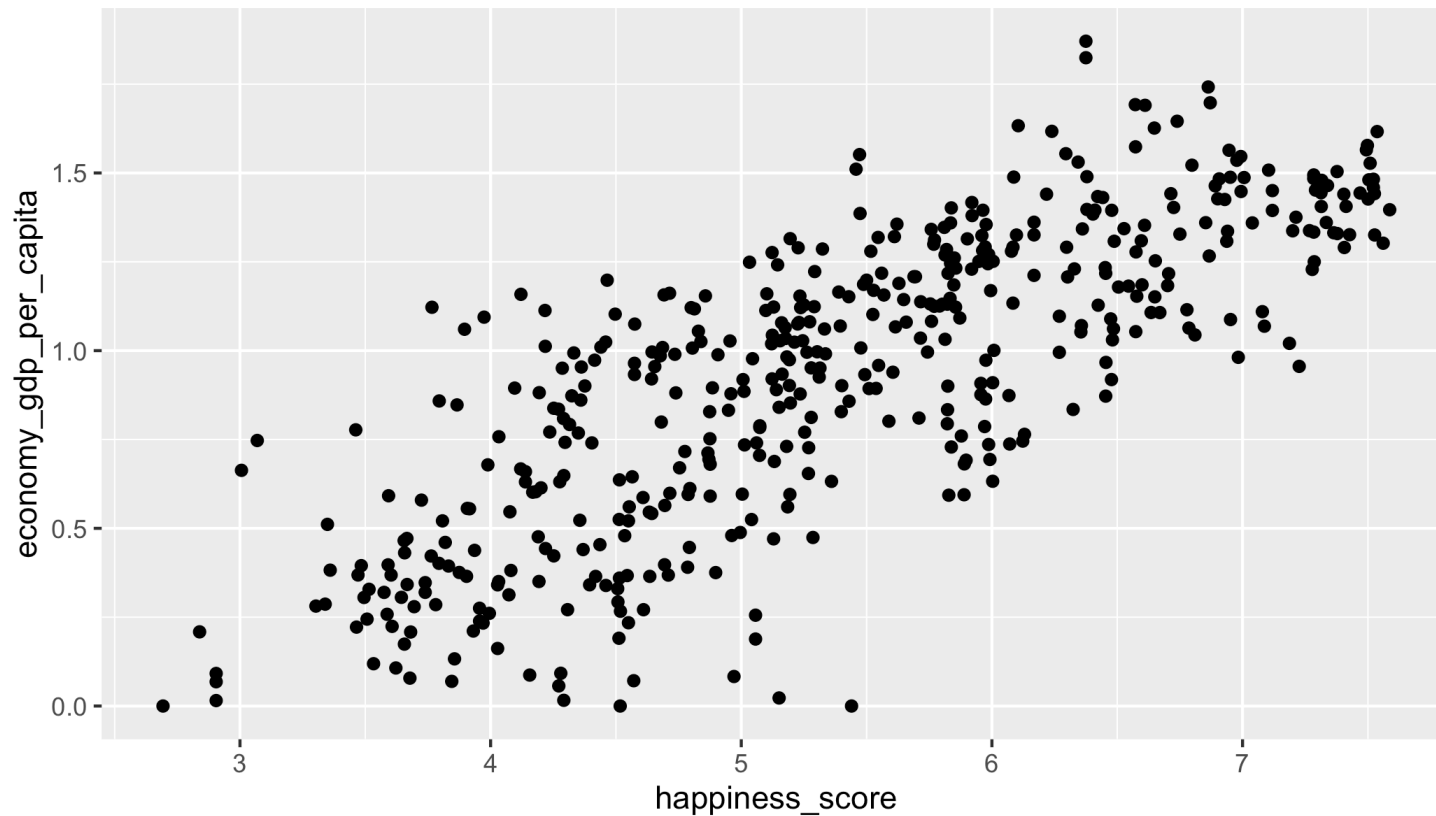# Exploratory Analysis

Let's start making some plots.

```
ggplot(data = whr_panel) +
  geom_point(mapping = aes(x = happiness_score, y = economy_gdp_per_capita))
```

Exploratory Analysis

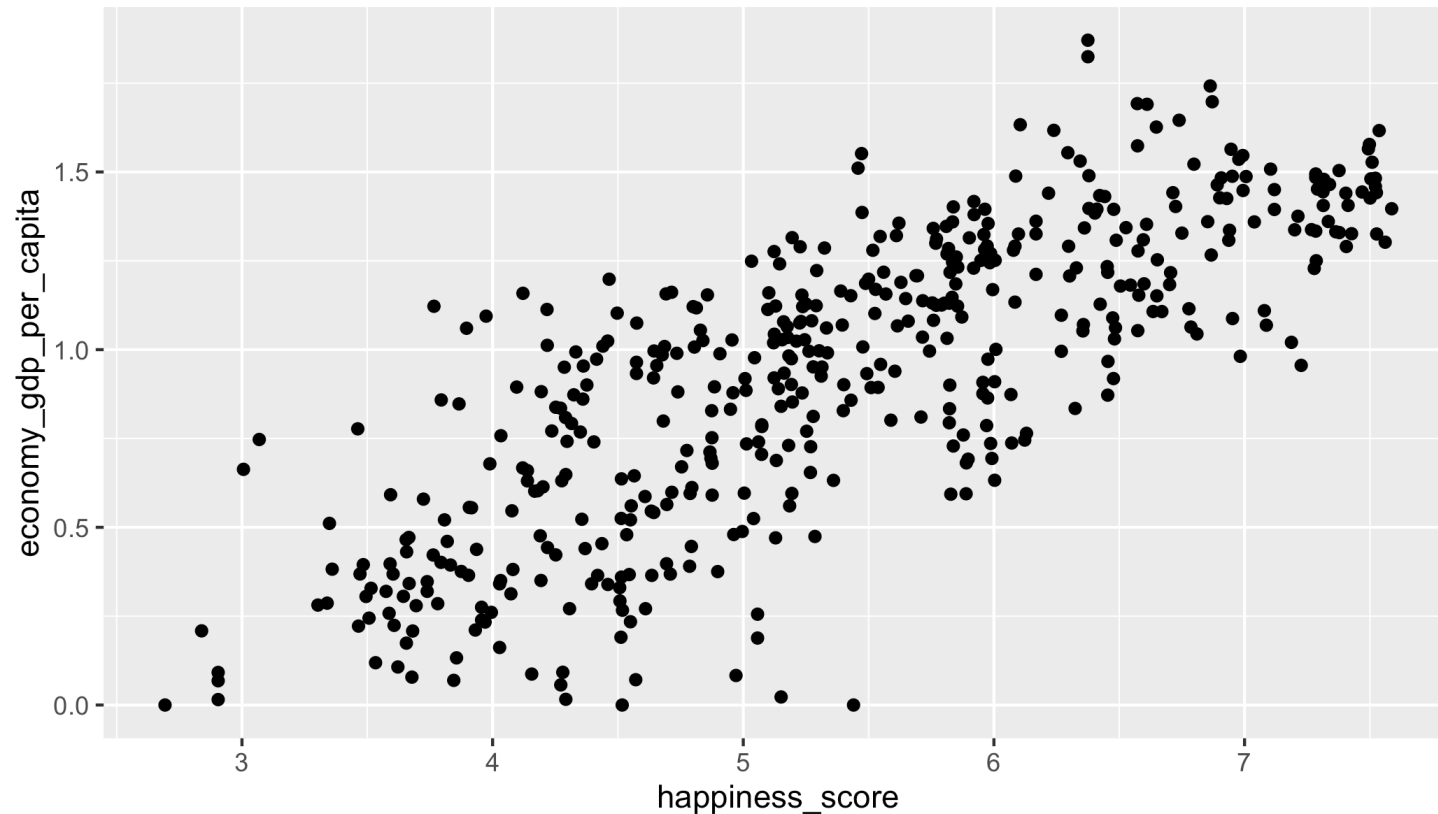We can also set up our mapping in the `ggplot()` function.

```
ggplot(data = whr_panel, aes(x = happiness_score, y = economy_gdp_per_capita)) +
  geom_point()
```

Exploratory Analysis

We can also set up the data outside the `ggplot()` function as follows:

```
whr_panel %>%
  ggplot(aes(x = happiness_score, y = economy_gdp_per_capita)) +
  geom_point()
```

Exploratory Analysis

I prefer to use the second way of structuring our ggplot.

1. First, setting our data;
2. pipe it;
3. then aesthetics;
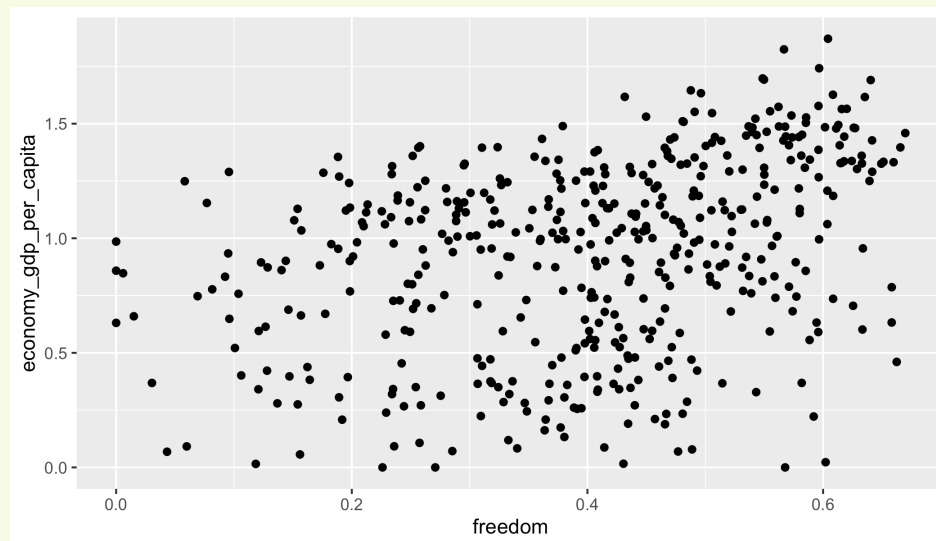4. and finally the geometries.

Both structures will work but this will make a difference if you want to load more datasets at the same time, and whether you would like to combine more geoms in the same ggplot. More on this in the following slides.

Exploratory Analysis

Exercise 2: Create a scatter plot with `x = freedom` and `y = economy_gdp_per_capita`.

Solution:

```
whr_panel %>%
  ggplot() +
  geom_point(aes(x = freedom, y = economy_gdp_per_capita))
```


`01:00`

Exploratory Analysis

The most common `geoms` are:

- `geom_bar()`, `geom_col()`: bar charts.
- `geom_boxplot()`: box and whiskers plots.
- `geom_density()`: density estimates.
- `geom_jitter()`: jittered points.
- `geom_line()`: line plots.
- `geom_point()`: scatter plots.

> If you want to know more about layers, you can refer to this.

Exploratory Analysis

In summary, our basic plots should have the following:

```
whr_panel %>%
  ggplot(
    aes(
      x = happiness_score,
      y = economy_gdp_per_capita
    )
  ) +
  geom_point()
```

The data we want to plot.

Exploratory Analysis

In summary, our basic plots should have the following:

```
whr_panel %>%
  ggplot(
    aes(
      x = happiness_score,
      y = economy_gdp_per_capita
    )
  ) +
  geom_point()
```

Columns (variables) to use for `x` and `y`

Exploratory Analysis

In summary, our basic plots should have the following:

```r
whr_panel %>%
  ggplot(
    aes(
      x = happiness_score,
      y = economy_gdp_per_capita
    )
  ) +
  geom_point()
```

How the plot is going to be drawn.

Exploratory Analysis

We can also **map** colors.

```
whr_panel %>%
ggplot(
    aes(
        x = happiness_score,
        y = economy_gdp_per_capita,
        color = region
    )
) +
    geom_point()
```
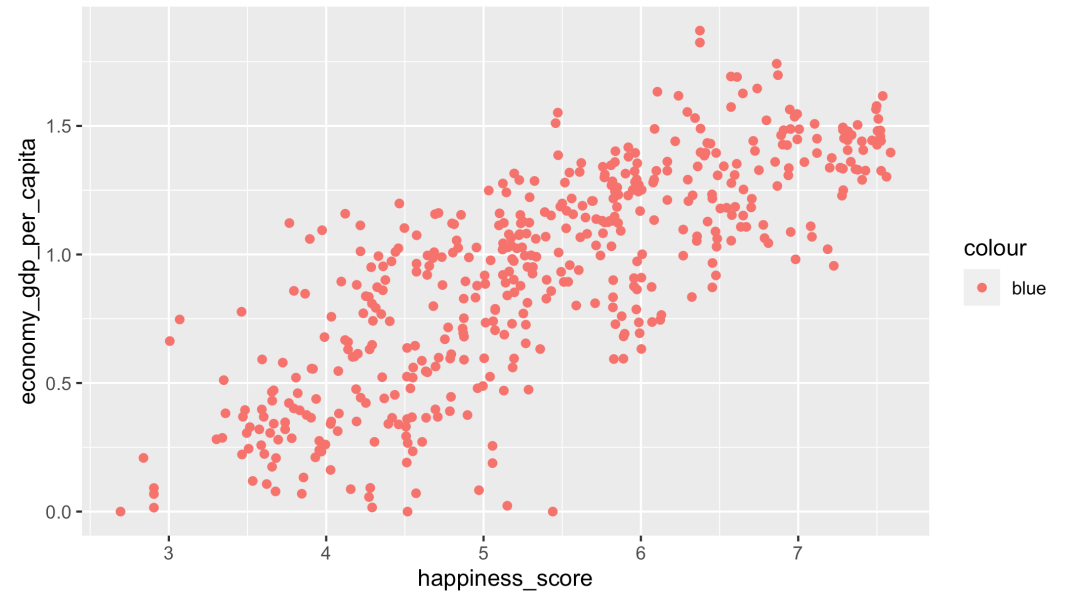
Exploratory Analysis

Let's try to do something different, try, instead of `region`, adding `color = "blue"` inside `aes()`.

- What do you think is the problem with this code?

```
whr_panel %>%
  ggplot(
    aes(
      x = happiness_score,
      y = economy_gdp_per_capita,
      color = "blue"
    )
  ) +
  geom_point()
```

Exploratory Analysis

In `ggplot2`, these settings are called **aesthetics**.

> "Aesthetics of the geometric and statistical objects".

We can set up:

- `position` : x, y, xmin, xmax, ymin, ymax, etc.
- `colors` : color and fill.
- `transparency` : alpha.
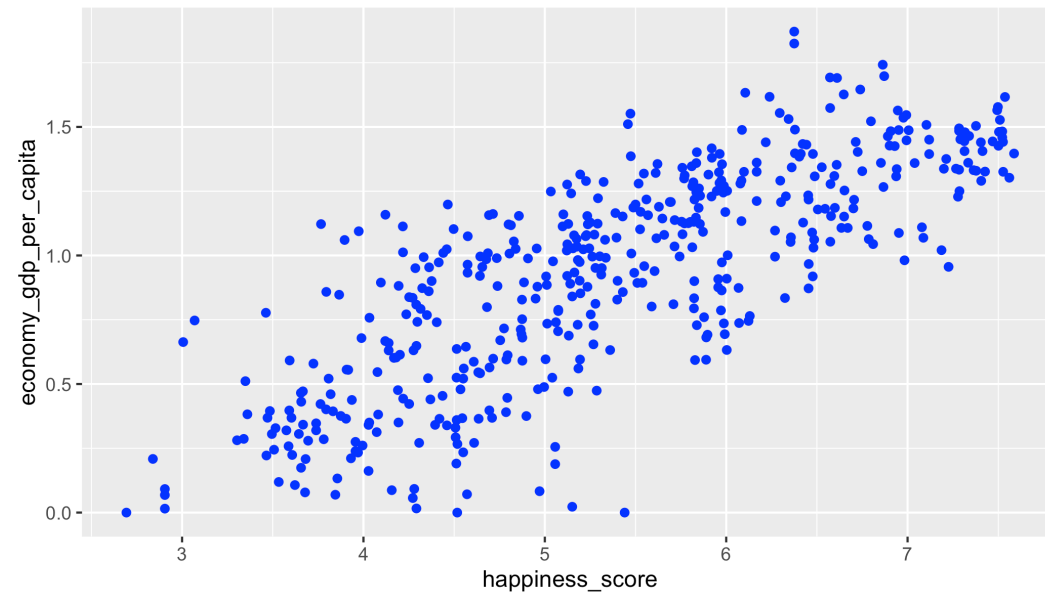- `sizes` : size and width.
- `shapes` : shape and linetype.

Notice that it is important to know where we are setting our aesthetics. For example:

- `geom_point(aes(color = region))` to color points based on the variable `region`
- `geom_point(color = "red")` to color all points in the same color.

Exploratory Analysis

Let's modify our last plot. Let's add `color = "blue"` inside `geom_point()`.

```
whr_panel %>%
  ggplot(
    aes(
      x = happiness_score,
      y = economy_gdp_per_capita
    )
  ) +
  geom_point(color = "blue")
```
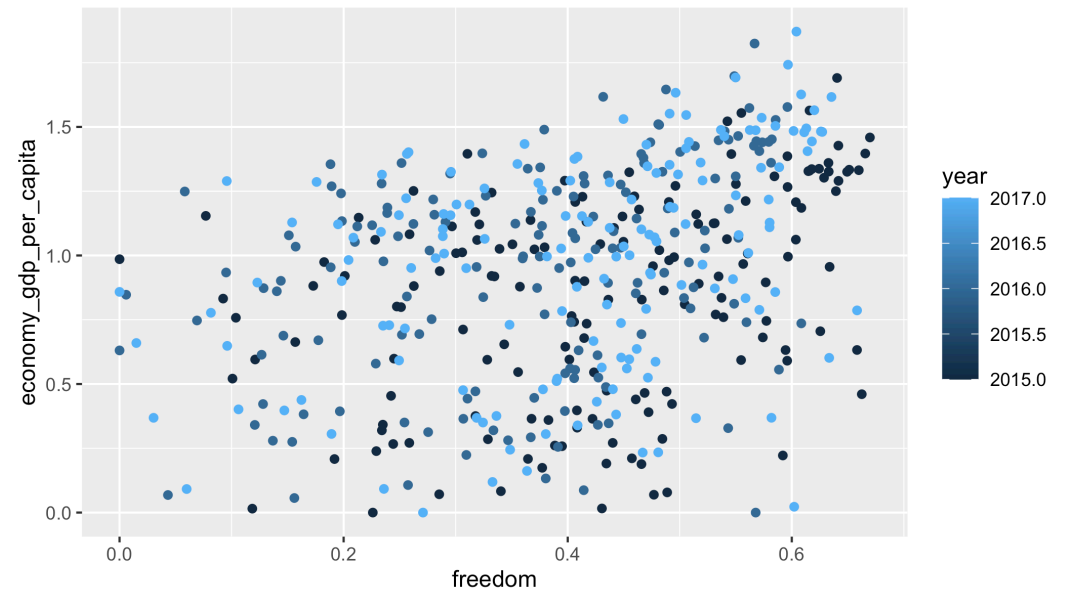
Exploratory Analysis

Exercise 3: Map colors per year for the freedom and gdp plot we did before. Keep in mind the type of the variable `year`.

Solution:

```
whr_panel %>%
  ggplot(
    aes(
      x = freedom,
      y = economy_gdp_per_capita,
      color = year
    )
  ) +
  geom_point()
```
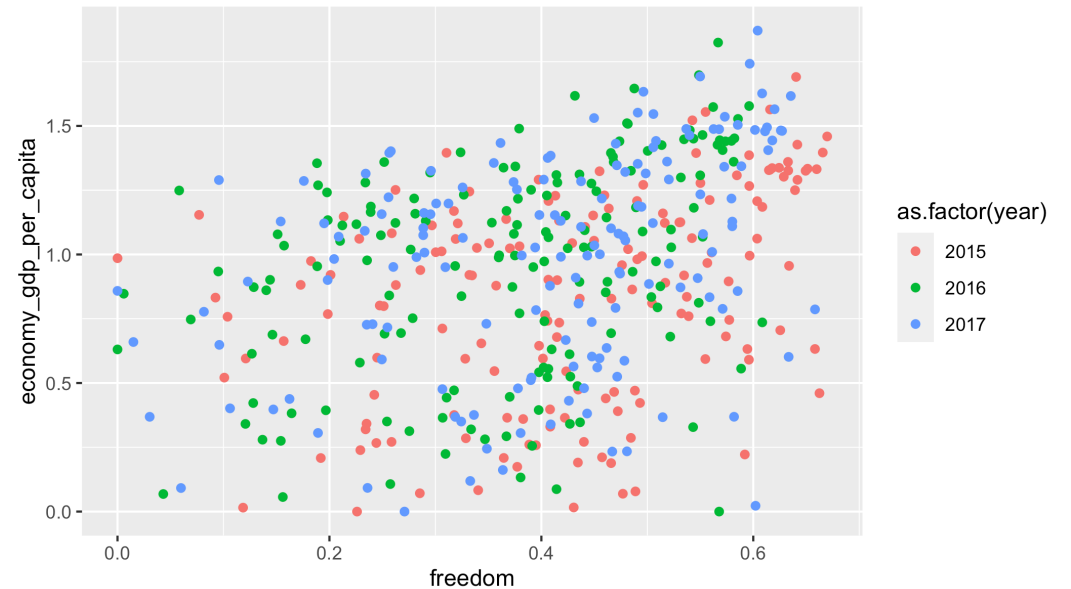

01:00

How do you think we could solve it?

- Change the variable `year` as: `as.factor(year)`.

```
whr_panel %>%
  ggplot(
    aes(
      x = freedom,
      y = economy_gdp_per_capita,
      color = as.factor(year)
    )
  ) +
  geom_point()
```
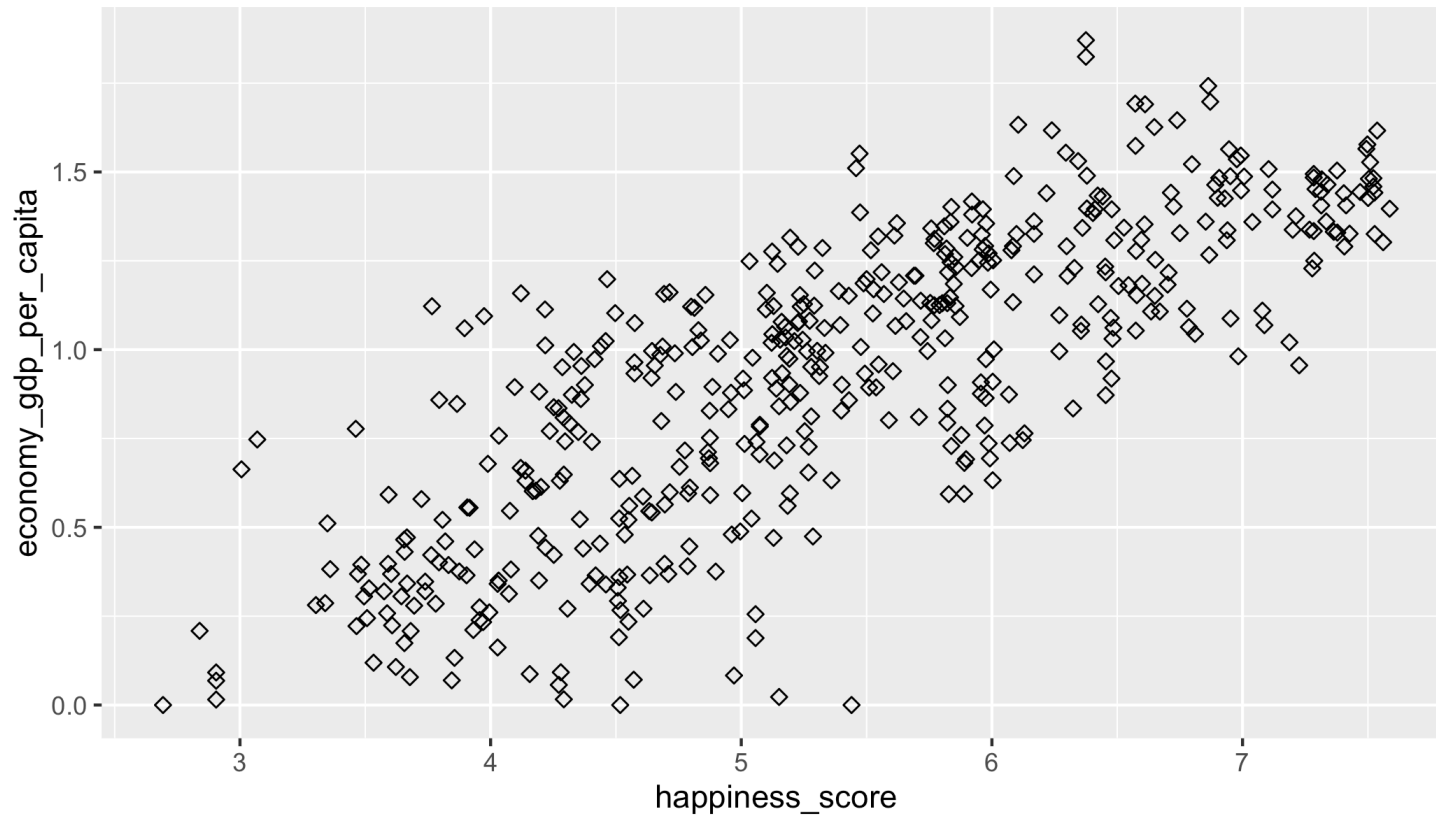
ggplot2: settings

ggplot2: settings

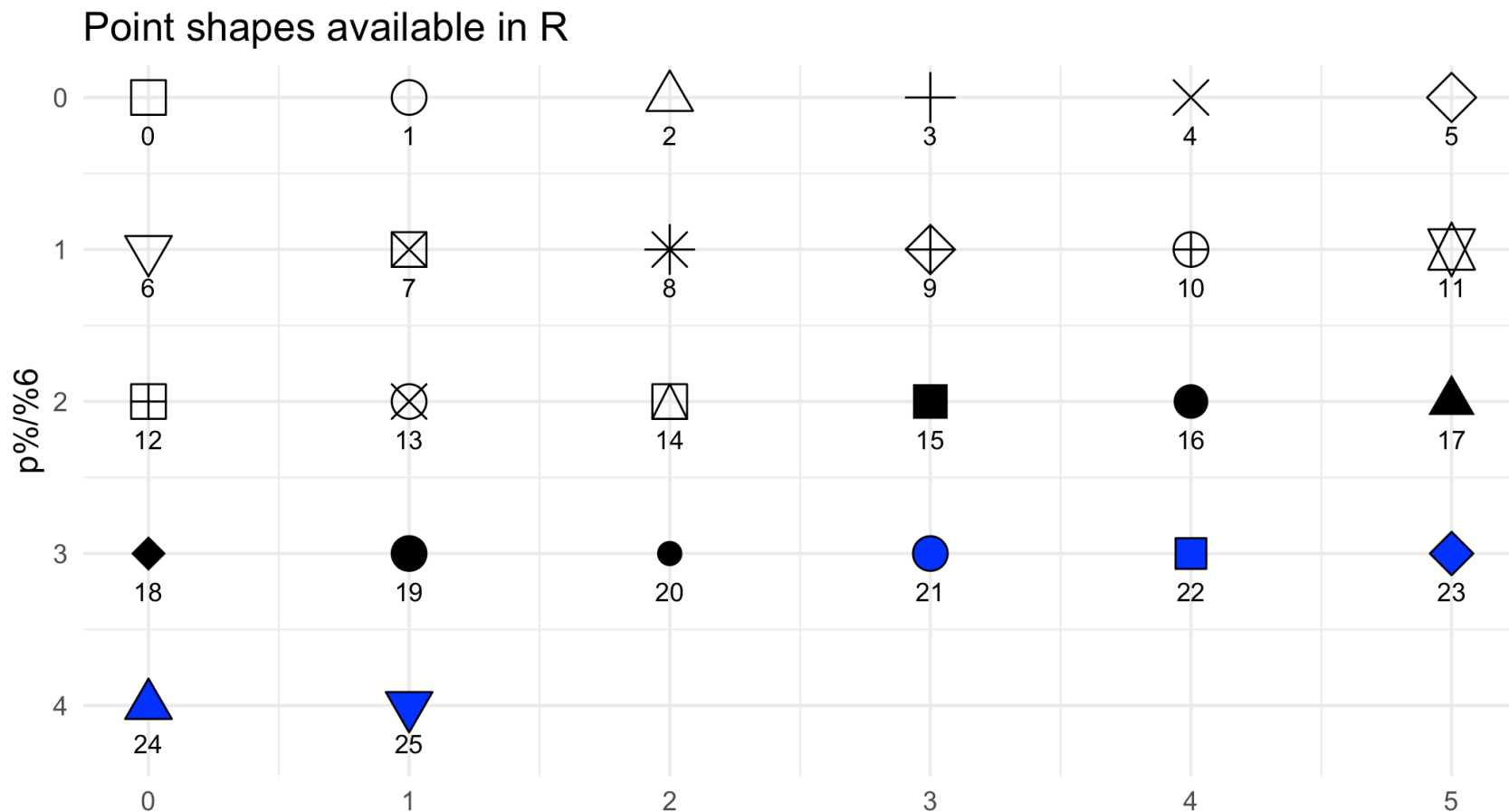Now, let's try to modify our plots. In the following slides, we are going to:

1. Change shapes.

2. Include more geoms.

3. Separate by regions.

4. Pipe and mutate before plotting.

5. Change scales.

6. Modify our theme.

ggplot2: shapes

```
whr_panel %>%
  ggplot(aes(x = happiness_score, y = economy_gdp_per_capita)) +
  geom_point(shape = 5)
```
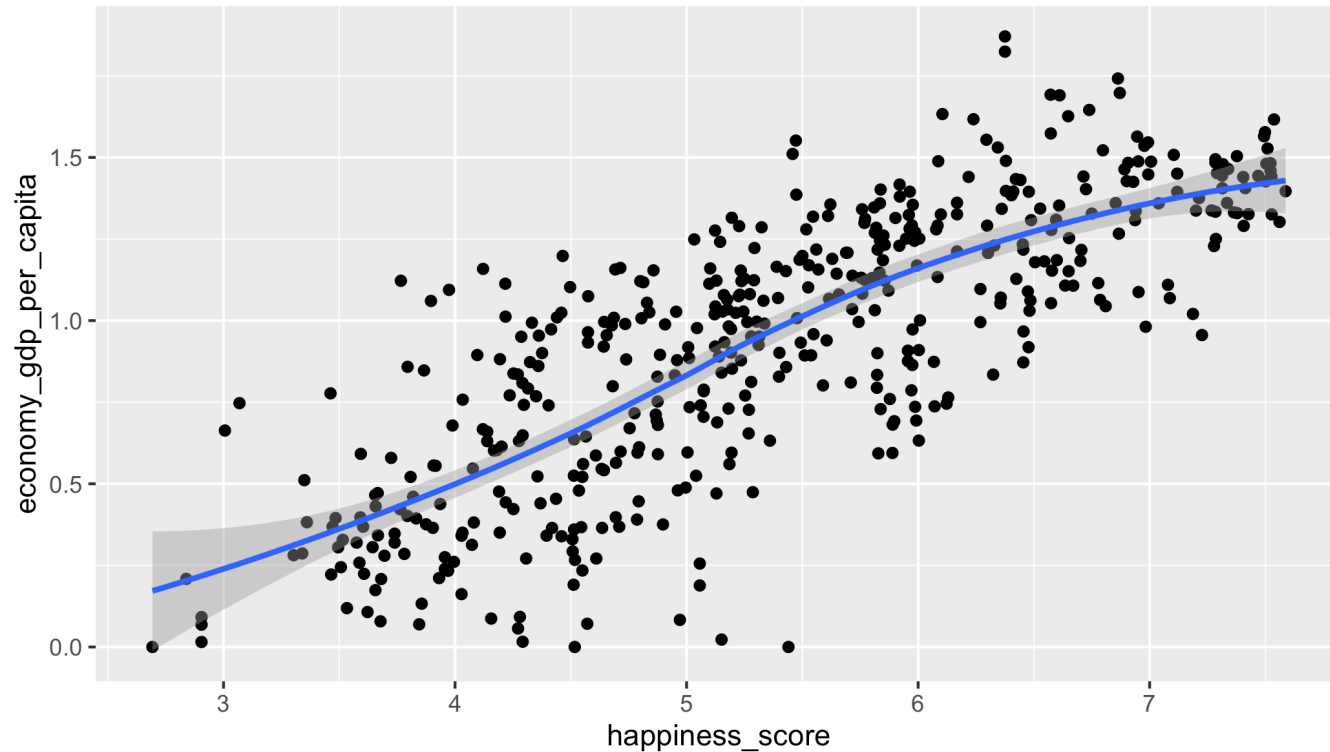
Point shapes available in R
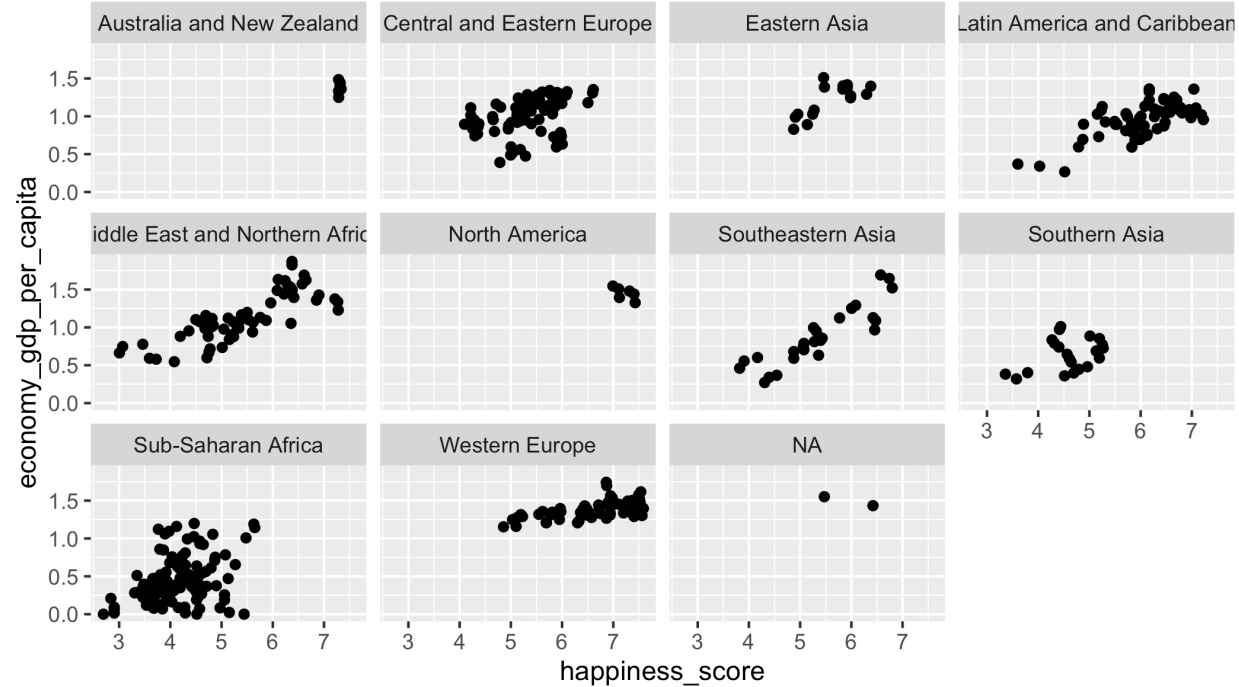
ggplot2: including more geoms

```
whr_panel %>%
  ggplot(aes(x = happiness_score,  y = economy_gdp_per_capita)) +
  geom_point() +
  geom_smooth()
```

```
## `geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```

ggplot2: Facets

```
whr_panel %>%
  ggplot(aes(x = happiness_score,  y = economy_gdp_per_capita)) +
  geom_point() +
  facet_wrap(~ region)
```
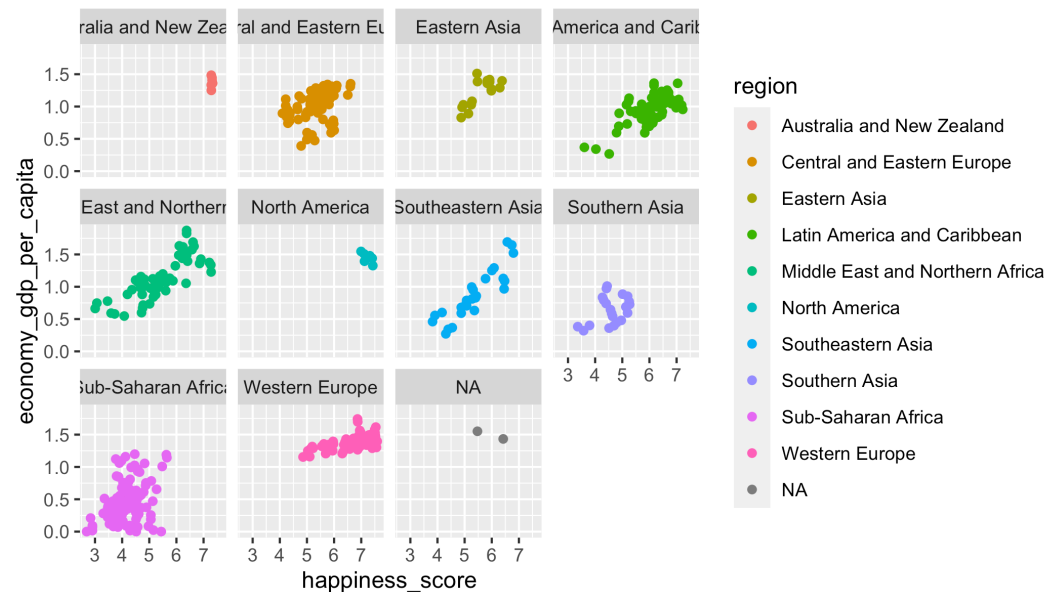
ggplot2: Colors and facets

Exercise 4: Use the last plot and add a color aesthetic per region.

Solution:

```
whr_panel %>%
  ggplot(
    aes(
      x = happiness_score,
      y = economy_gdp_per_capita,
      color = region
    )
  ) +
  geom_point() +
  facet_wrap(~ region)
```


`01:00`

ggplot2: Pipe and mutate before plotting

Let's imagine now, that we would like to transform a variable before plotting.

R Code   Plot

```r
whr_panel <- whr_panel %>%
  mutate(
    latam = region == "Latin America and Caribbean"
  )

whr_panel %>%
  filter(
      !is.na(latam) # Make sure that we don't include missing values in our graph
  ) %>%
  ggplot(
    aes(
      x = happiness_score, y = economy_gdp_per_capita,
      color = latam)
  ) +
  geom_point()
```
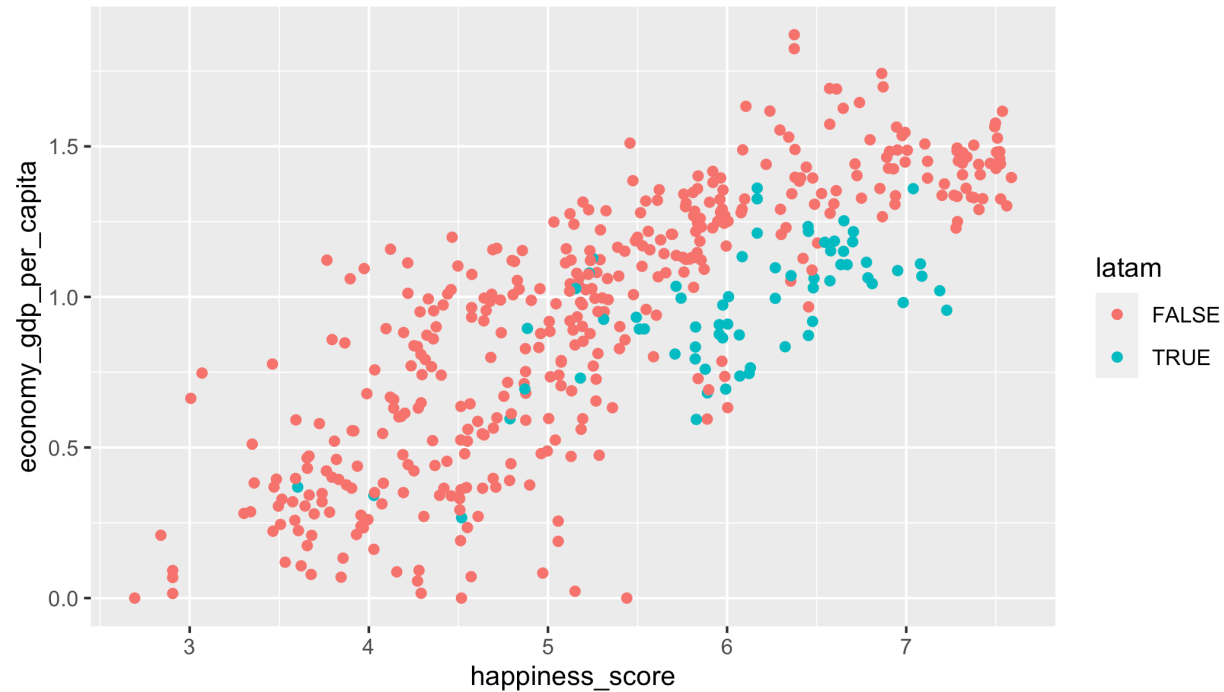
ggplot2: Pipe and mutate before plotting

Let's imagine now, that we would like to transform a variable before plotting.
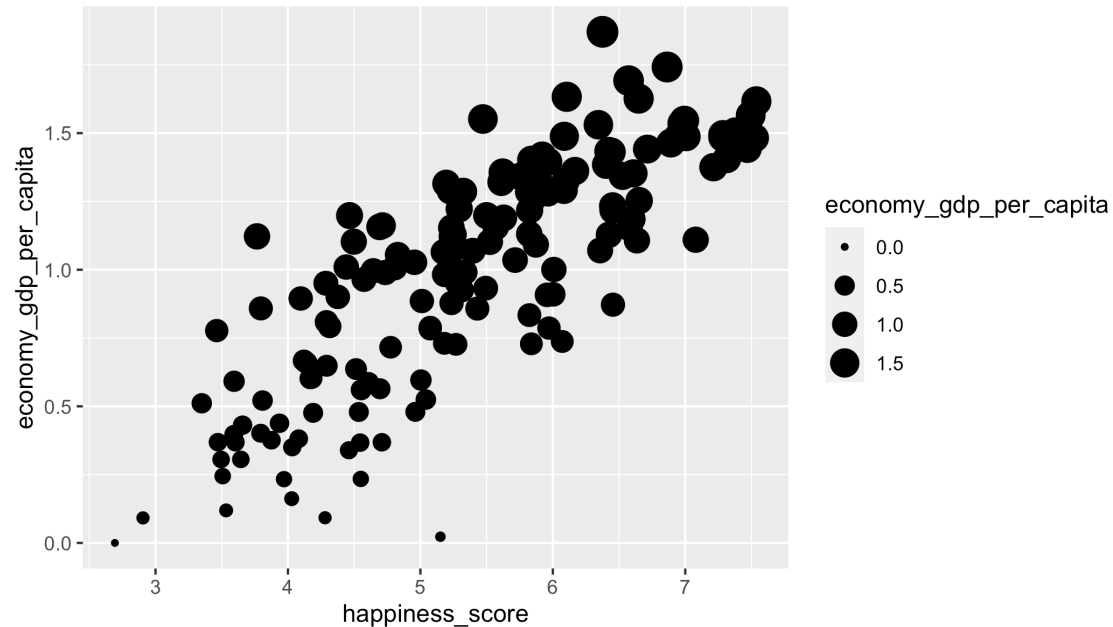
R Code   **Plot**

ggplot2: geom's sizes

We can also specify the size of a geom, either by a variable or just a number.
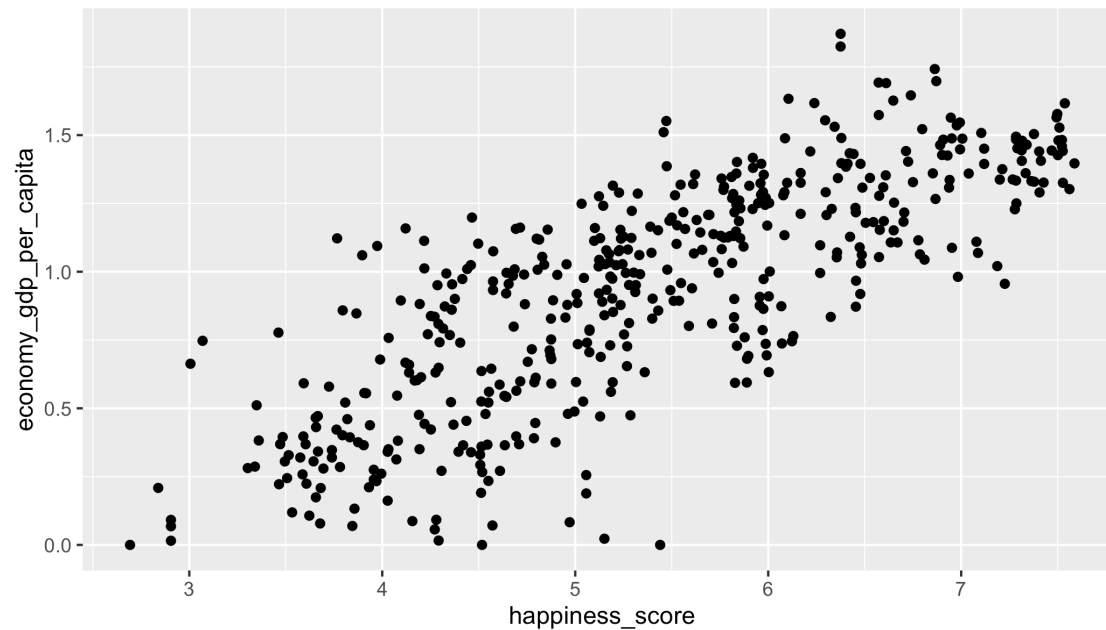
```r
whr_panel %>%
  filter(year == 2017) %>%
  ggplot(aes(x = happiness_score,  y = economy_gdp_per_capita)) +
  geom_point(aes(size = economy_gdp_per_capita))
```

ggplot2: Changing scales
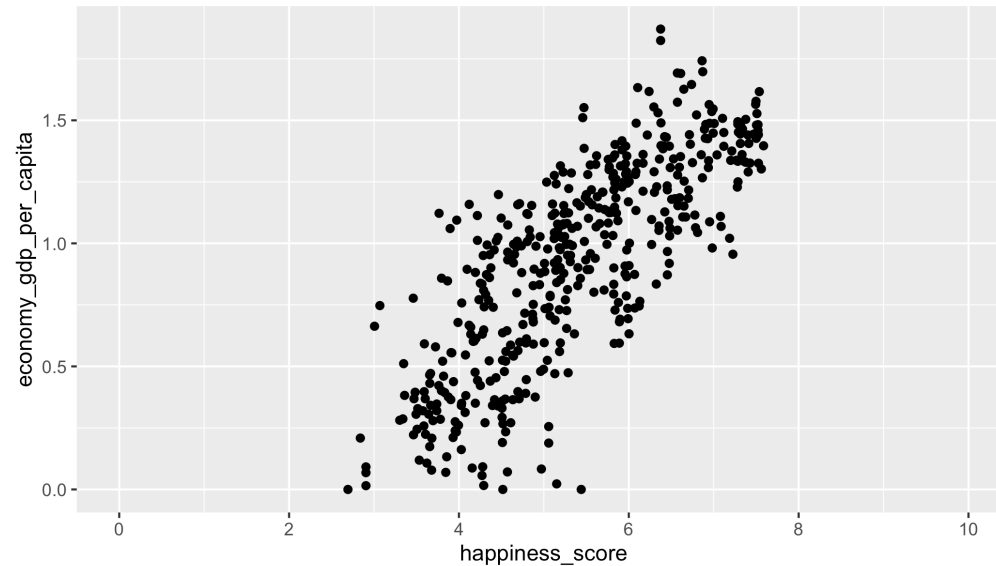
Linear   Log

```
ggplot(data = whr_panel,
       aes(x = happiness_score,
           y = economy_gdp_per_capita)) +
  geom_point()
```

ggplot2: Changing scales

Linear   Log

```
ggplot(data = whr_panel,
       aes(x = happiness_score,
           y = economy_gdp_per_capita)) +
  geom_point() +
  scale_x_continuous(limits = c(0, 10),
                     breaks = c(0, 2, 4, 6, 8, 10))
```

ggplot2: Themes

Let's go back to our plot with the `latam` dummy.

We are going to do the following to this plot:

1. Filter only for the year 2015.
2. Change our theme.
3. Add correct labels.
4. Add some annotations.
5. Modify our legends.

ggplot2: Labels

R Code   Plot

```
whr_panel %>%
  filter(
      !is.na(latam) # Make sure that we don't include missing values in our graph
  ) %>%
  filter(year == 2015) %>%
  ggplot(aes(x = happiness_score, y = economy_gdp_per_capita,
             color = latam)) +
  geom_point() +
  labs(
    x = "Happiness Score",
    y = "GDP per Capita",
    title = "Happiness Score vs GDP per Capita, 2015"
  )
```

ggplot2: Labels

R Code | Plot

Happiness Score vs GDP per Capita, 2015

ggplot2: Legends
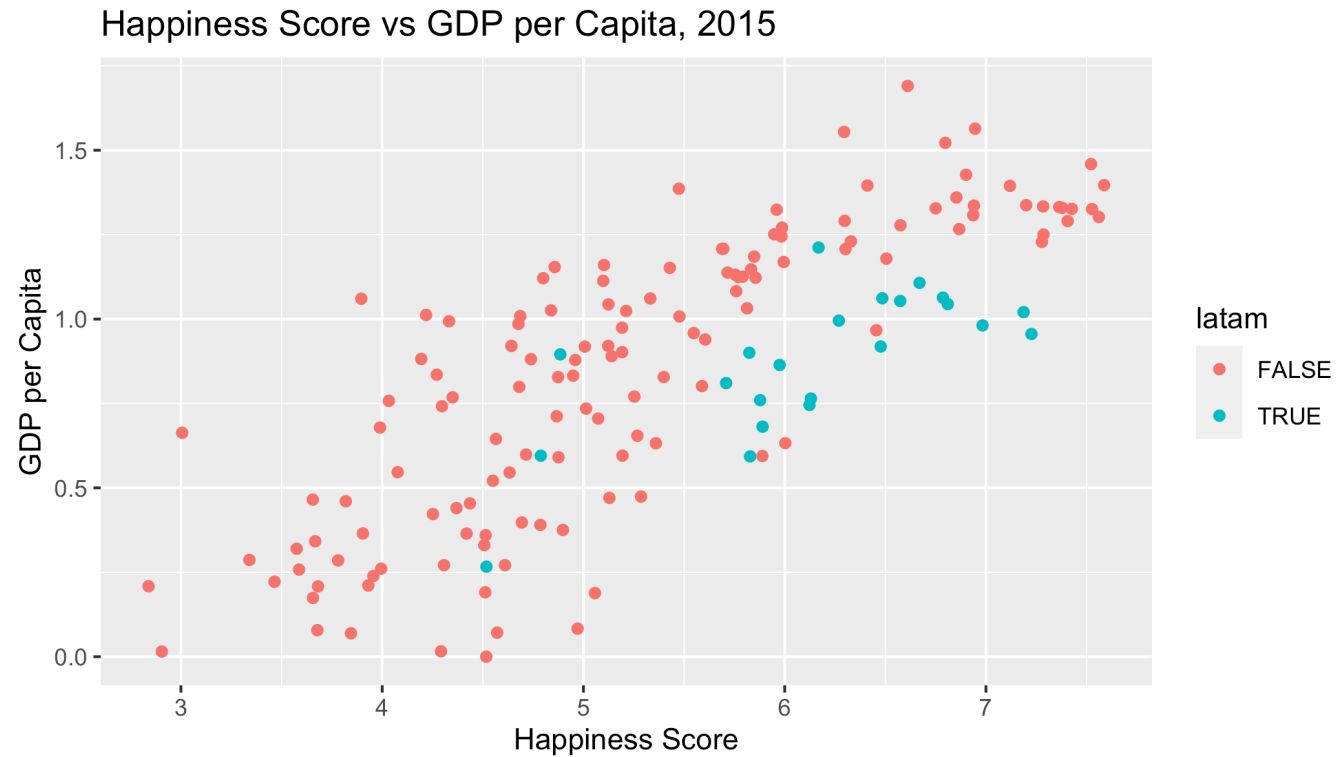
```r
whr_panel %>%
  filter(
    !is.na(latam) # Make sure that we don't include missing values in our graph
  ) %>%
  filter(year == 2015) %>%
  ggplot(aes(x = happiness_score, y = economy_gdp_per_capita,
             color = latam)) +
  geom_point() +
  scale_color_discrete(labels = c("No", "Yes")) +
  labs(
    x = "Happiness Score",
    y = "GDP per Capita",
    color = "Country in Latin America\nand the Caribbean",
    title = "Happiness Score vs GDP per Capita, 2015"
  )
```

ggplot2: Legends

R Code   Plot

Happiness Score vs GDP per Capita, 2015
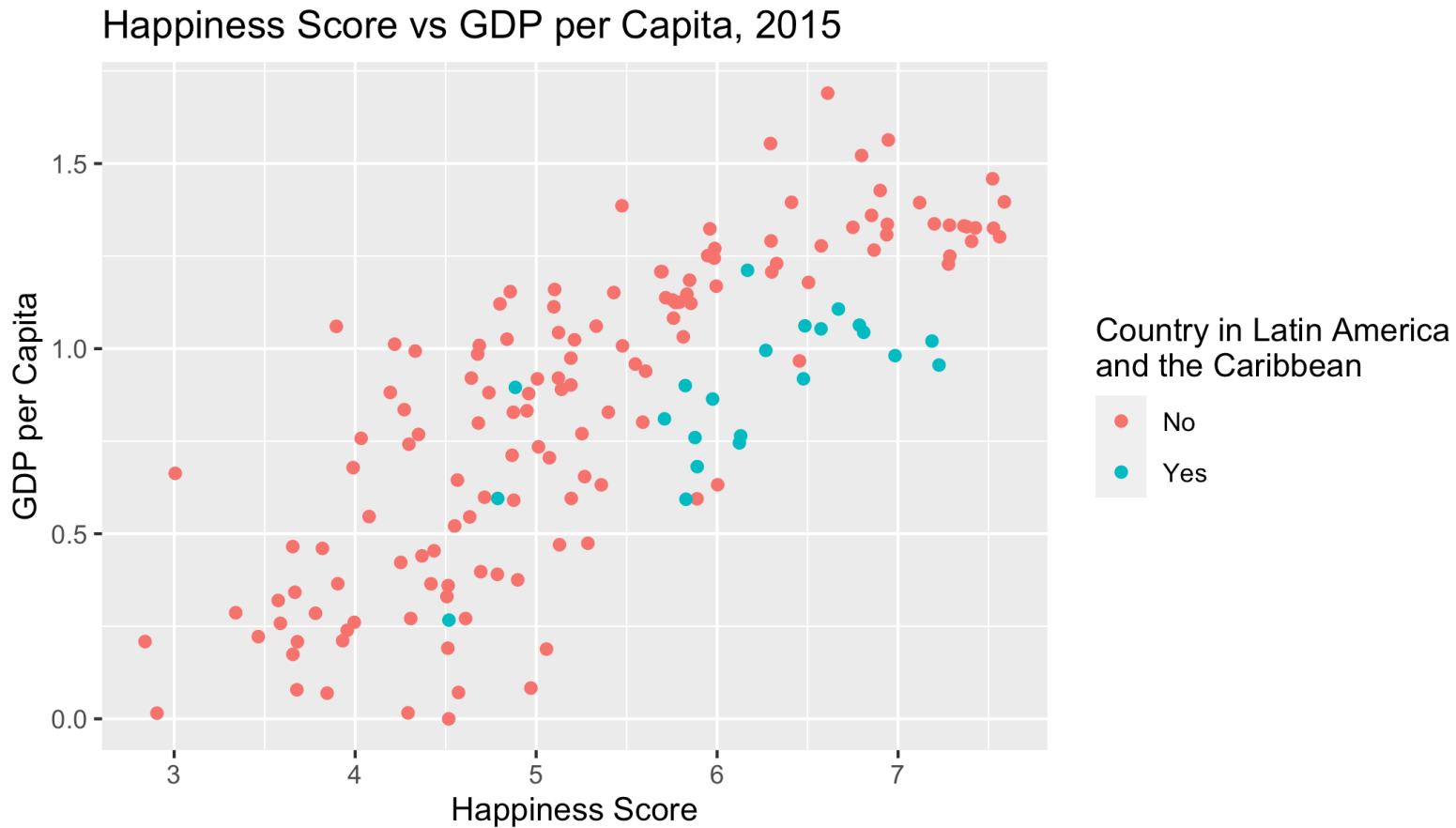
ggplot2: Themes

R Code   Plot

```r
whr_panel %>%
  filter(
      !is.na(latam) # Make sure that we don't include missing values in our graph
  ) %>%
  filter(year == 2015) %>%
  ggplot(aes(x = happiness_score, y = economy_gdp_per_capita,
             color = latam)) +
  geom_point() +
  scale_color_discrete(labels = c("No", "Yes")) +
  labs(
    x = "Happiness Score",
    y = "GDP per Capita",
    color = "Country in Latin America\nand the Caribbean",
    title = "Happiness Score vs GDP per Capita, 2015"
  ) +
  theme_minimal()
```

ggplot2: Themes

Happiness Score vs GDP per Capita, 2015

ggplot2: Themes

The `theme()` function allows you to modify each aspect of your plot. Some arguments are:

```
theme(
    # Title and text labels
    plot.title = element_text(color, size, face),
    # Title font color size and face
    legend.title = element_text(color, size, face),
    # Title alignment. Number from 0 (left) to 1 (right)
    legend.title.align = NULL,
    # Text label font color size and face
    legend.text = element_text(color, size, face),
    # Text label alignment. Number from 0 (left) to 1 (right)
    legend.text.align = NULL,
)
```

More about these modification can be found here

ggplot2: Color palettes

We can also add color palettes using other packages such as: `RColorBrewer`, `viridis` or funny ones like the `wesanderson` package. So, let's add new colors.

- First, install the `RColorBrewer` package.

```r
# install.packages("RColorBrewer")
library(RColorBrewer)
```

- Let's add `scale_color_brewer(palette = "Dark2")` to our ggplot.

ggplot2: Color palettes
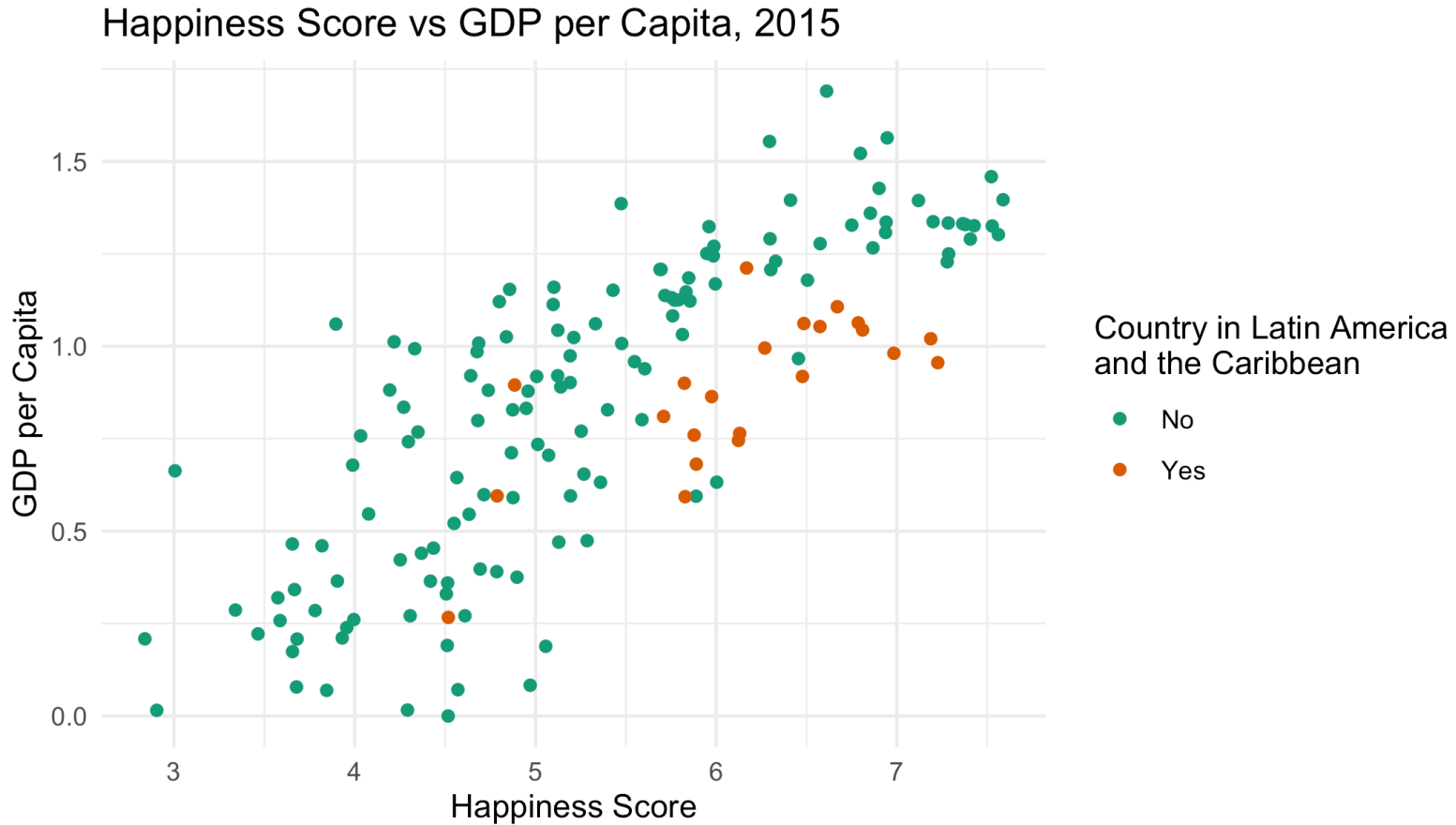
R Code   Plot

```r
whr_panel %>%
  filter(
      !is.na(latam) # Make sure that we don't include missing values in our graph
  ) %>%
  filter(year == 2015) %>%
  ggplot(aes(x = happiness_score, y = economy_gdp_per_capita,
            color = latam)) +
  geom_point() +
  scale_color_brewer(palette = "Dark2", labels = c("No", "Yes")) +
  labs(
    x = "Happiness Score",
    y = "GDP per Capita",
    color = "Country in Latin America\nand the Caribbean",
    title = "Happiness Score vs GDP per Capita, 2015"
  ) +
  theme_minimal()
```

ggplot2: Color palettes

R Code   Plot

ggplot2: Color palettes

My favorite color palettes packages:

1. ghibli
2. LaCroixColoR
3. NineteenEightyR
4. nord
5. palettetown
6. quickpalette
7. wesanderson

Saving a plot

Saving a plot

Remember that in R we can always assign our functions to an object. In this case, we can assign our `ggplot2` code to an object called fig as follows.

```
fig <- whr_panel %>%
  filter(
      !is.na(latam) # Make sure that we don't include missing values in our graph
  ) %>%
  filter(year == 2015) %>%
  ggplot(aes(x = happiness_score, y = economy_gdp_per_capita,
            color = latam)) +
  geom_point() +
  scale_color_discrete(labels = c("No", "Yes")) +
  labs(
    x = "Happiness Score",
    y = "GDP per Capita",
    color = "Country in Latin America\nand the Caribbean",
    title = "Happiness Score vs GDP per Capita, 2015"
  ) +
  theme_minimal()
```

Therefore, if you want to plot it again, you can just type `fig` in the console.

Saving a plot

Exercise 5: Save a ggplot under the name `fig_*YOUR INITIALS*`. Use the `ggsave()` function. You can either include the function after your plot or, save the ggplot first as an object and then save the plot.

The syntax is `ggsave(OBJECT, filename = FILEPATH, heigth = ..., width = ..., dpi = ...)`.

Solution:

```
ggsave(
    fig,
    filename = here("DataWork","Output","Raw","fig_MA.png"),
    dpi = 750,
    scale = 0.8,
    height = 8,
    width = 12
)
```

`01:00`

And that's it for this session. Join us tomorrow for data analysis. Remember to submit your feedback!

References and recommendations

References and recommendations

- **ggplot tricks**:

  - Tricks and Secrets for Beautiful Plots in R by Cédric Scherer: https://github.com/z3tt/outlierconf2021

- **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

Appendix: interactive graphs

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!

Extra exercise: Interactive graphs.

- Load the plotly package
- Pass that object with the last plot you created to the ggplotly() function

Interactive graphs

R Code   Plot

```r
# Load package
library(plotly)

# Use ggplotly to create an interactive plot
ggplotly(fig) %>%
  layout(legend = list(orientation = "h", x = 0.4, y = -0.2))
```

Interactive graphs

Happiness Score vs GDP per Capita, 2015