

Module 3: R

Visualization

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Course Documents

- Visit: <https://github.com/anjalisilva/IntroductionToR>
- All course material will be available via IntroductionToR GitHub repository (<https://github.com/anjalisilva/IntroductionToR>). Folder structure is as follows:
 - Lessons - All files: These folder contains all files.
 - **Lessons - Data only**: This folder contains data only.
 - **Lessons - Lesson Plans only**: This folder contains lesson plans only.
 - **Lessons - PDF only**: This folder contains slide PDFs only.
 - README - README file
 - .gitignore - Files to ignore specified by instructor

Course Contacts

- Instructor: Anjali Silva Email: a.silva@utoronto.ca (Must use the subject line DSI-IntroR. E.g., DSI-IntroR: Inquiry about Lecture I.)
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Overview

- ggplot
- Initializing plots, specifying variables, and choosing chart types
- Customizing plots with labels, axes, color, size, multiple graph types, multiple plots, and overall look

(Wickham and Grolemund, 2017, Chapter 3; Healy, 2018, Chapter 3; Alexander, 2022, Chapter 6)

ggplot

ggplot

ggplot2 is a package that allows us to make graphics in R. It's loaded with the tidyverse.

Initializing a plot

the `ggplot()` function initializes the plot. In the arguments, you will identify the base of your plot. This includes:

- the data we want to graph from
- the aesthetics we will use

What doesn't go in the `ggplot()` function:

- the type of graph we want
- the way we want the axes to look
- the labels we want

```
ggplot(data = my_data, mapping = aes())
```

Aesthetic

In the **mapping** argument, we specify our aesthetic using **aes()**

This is where we indicate what variable we want for the x axis, the y axis, the color, or any other feature that the plot in question might have.

```
aes(x = variable1,  
    y = variable2,  
    shape = variable3,  
    color = variable4,  
    size = variable5,  
    fill = variable6)
```

In combination

This takes **data** and passes it to `ggplot`, which initializes a plot using that data and specifies that `variable1` will be represented on the x axis and `variable2` on the y axis.

```
data %>%  
  ggplot(aes(x = variable1, y = variable2))
```


Adding layers

After initializing, you still won't have a plot. You have to add layers -- which includes the type of plot you want, as well as tweaks and formatting specifics.

When we add layers to a ggplot object, we use the **+** between lines:

```
data %>%  
  ggplot(aes(x = variable1, y = variable2)) +  
    # a layer +  
    # another layer
```

Geoms

Geom layers add types of plot. There are more than 40 geoms! Some common ones:

Bar plots

```
geom_bar()
```

Histograms

```
geom_histogram()
```

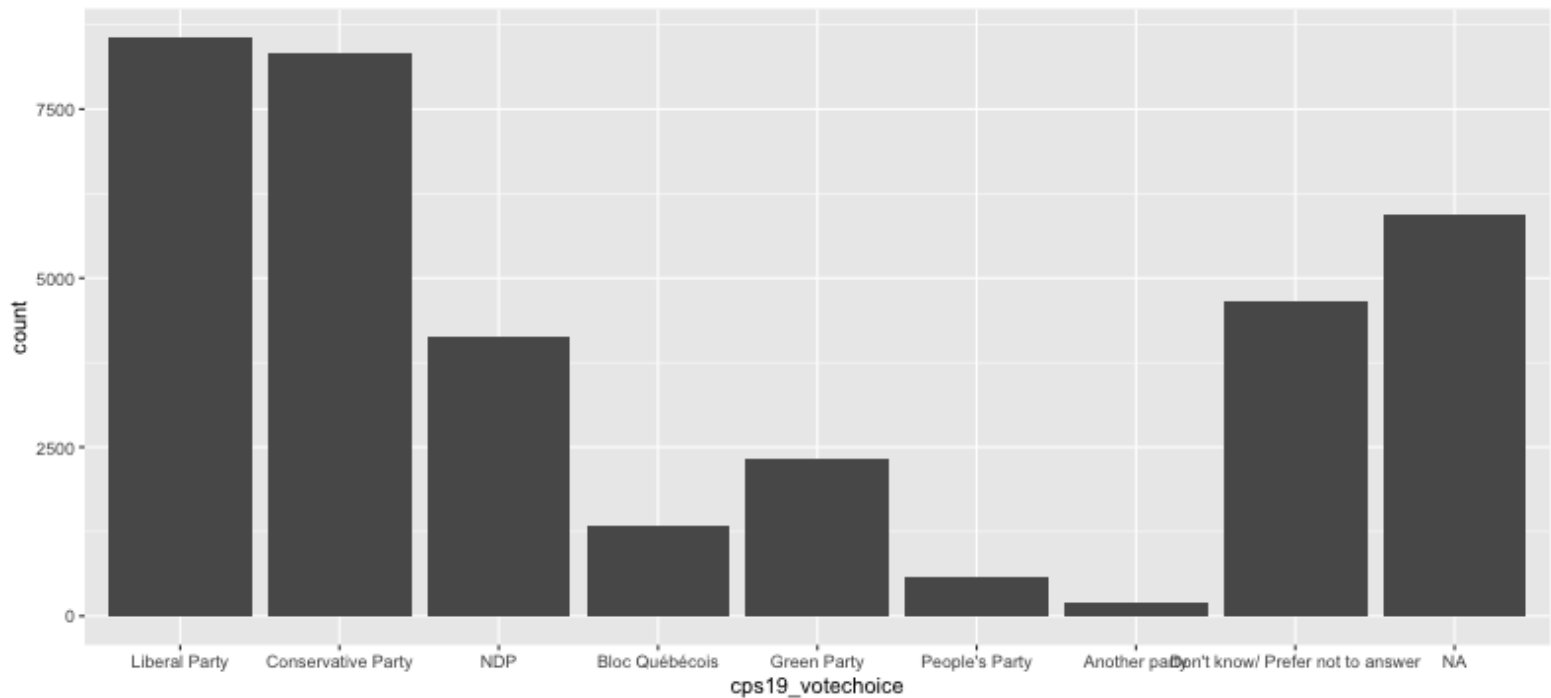
Scatterplots

```
geom_point()
```

Examples

Bar plot

```
CES_data %>%  
  ggplot(aes(x = cps19_votechoice, )) +  
  geom_bar()
```



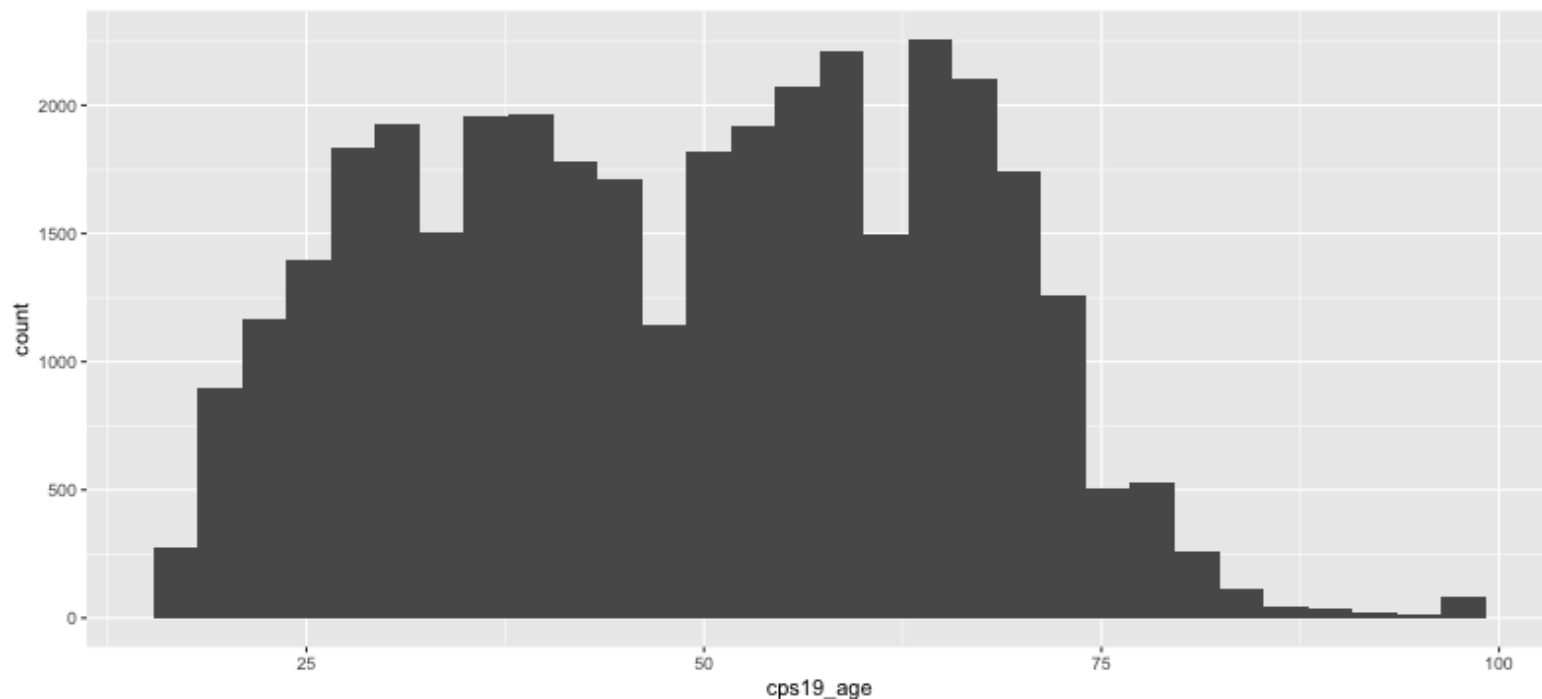
Options for barplots

These are the defaults in a `geom_bar`:

```
geom_bar(  
  stat = "count", # can change to "prop" for proportion  
  position = "stack", # can change to "dodge" or "fill"  
  width = NULL, # can put a bar width here  
  na.rm = FALSE, # can remove NAs  
  orientation = NA, # can specify "x" or "y"  
  show.legend = NA # can add or remove a legend  
)
```

Histogram

```
CES_data %>%  
  mutate(age = 90 - cps19_yob) %>%  
  ggplot(aes(x = cps19_age)) +  
  geom_histogram()
```

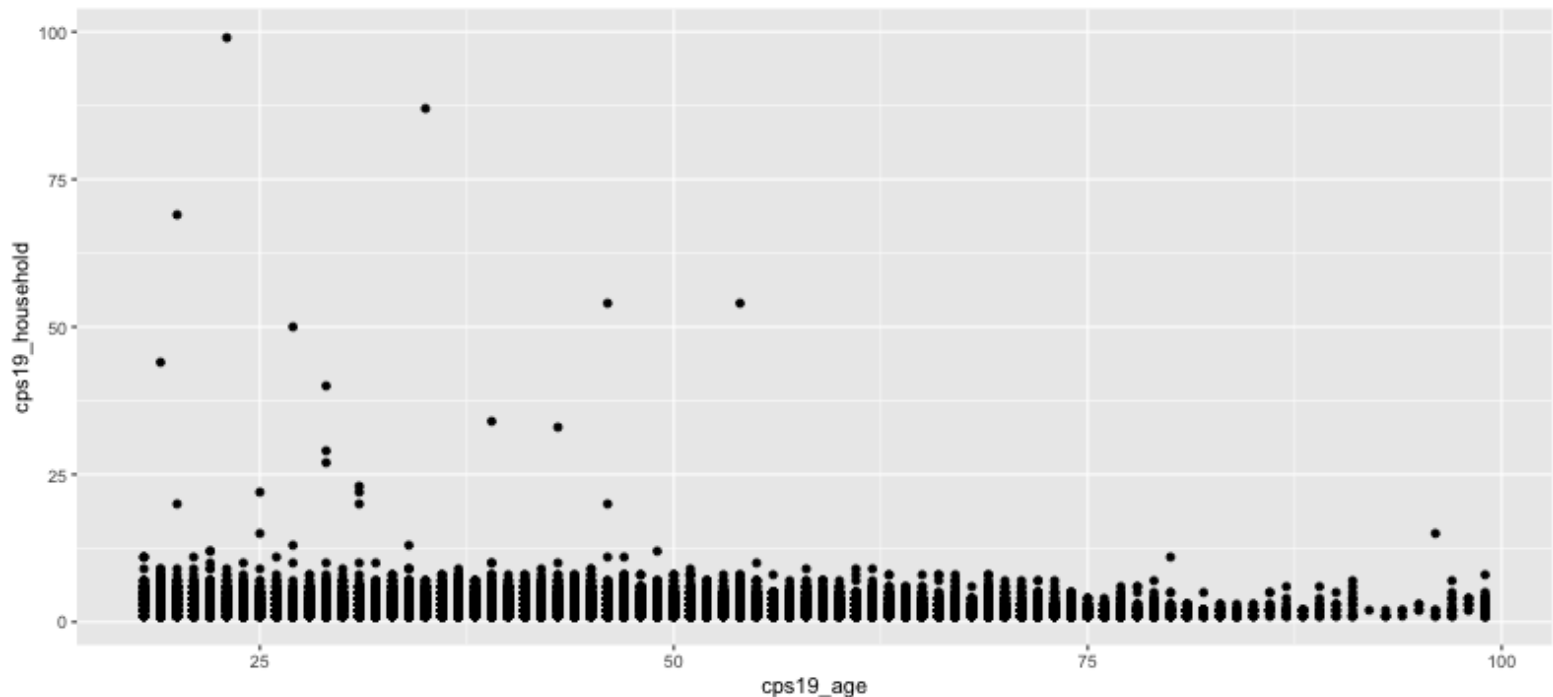


Options for histograms

```
geom_histogram(  
  stat = "bin", # can change to "count"  
  position = "stack", # can change to "identity", "dodge", or "fill"  
  binwidth = NULL, # can specify the range of each bin  
  bins = NULL, # can specify the number of bins  
  na.rm = FALSE, # can tell it to ignore NAs  
  orientation = NA, # can specify "x" or "y"  
  show.legend = NA # can add or remove a legend  
)
```

Scatter plot

```
CES_data %>%  
  mutate(age = 90 - cps19_yob) %>%  
  ggplot(aes(x = cps19_age, y = cps19_household)) +  
  geom_point()
```



Options for scatterplots

```
geom_point(  
  position = "identity", # can change to "jitter"  
  na.rm = FALSE, # can ignore NAs  
  show.legend = NA # can add or remove a legend  
)
```

Exercises

Using different variables:

1. Make a barplot
2. Make a histogram
3. Make a scatterplot

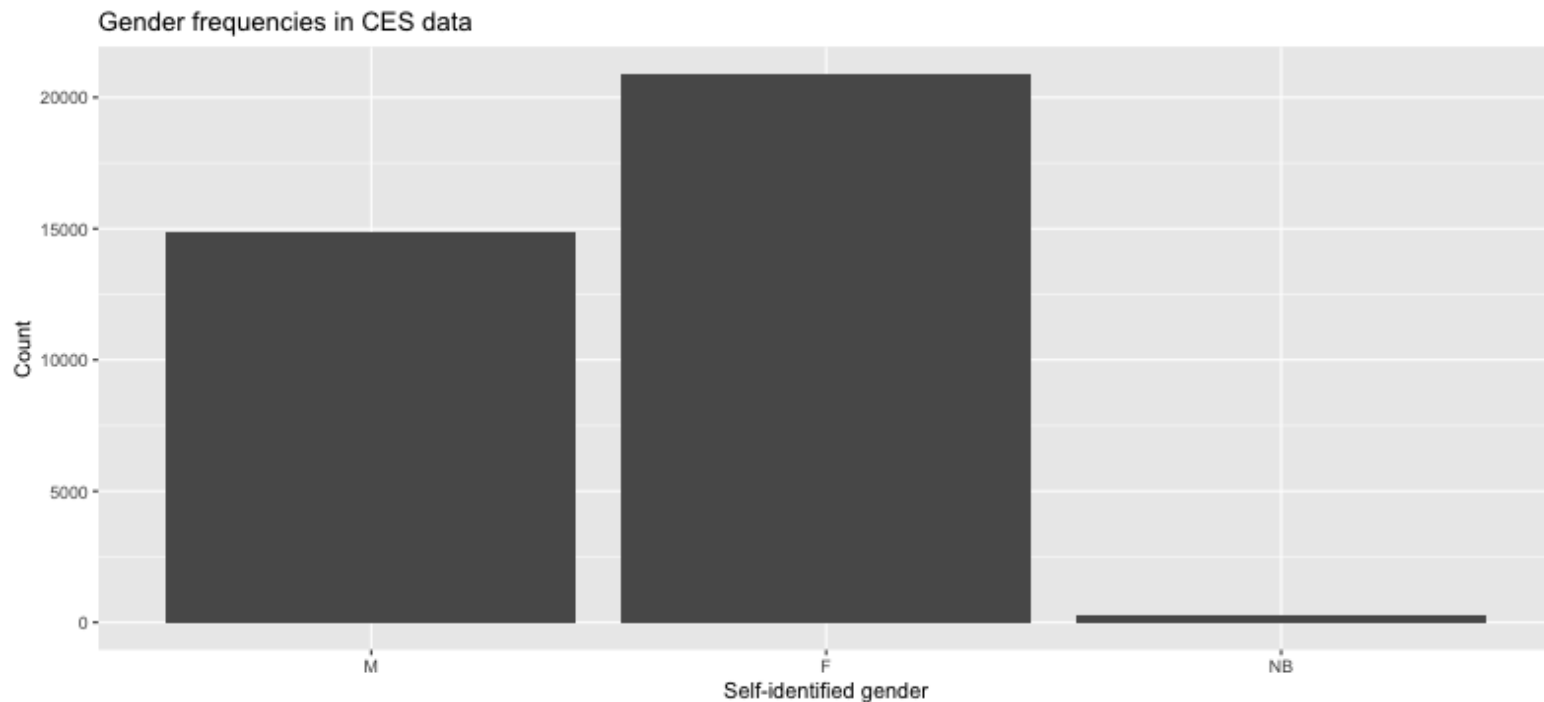
Customizing plots

Labels

We can change the way that labels appear to improve the look and readability.

```
labs(x = "X name",  
     y = NULL,  
     title = "Title")
```

```
CES_data %>%  
  ggplot(aes(x = cps19_gender)) +  
  geom_bar() +  
  labs(x = "Self-identified gender",  
       y = "Count",  
       title = "Gender frequencies in CES data")
```



Axes

How we change the axes depends on what types of variables we have.

The layers take the form: `scale_<which axis>_<what type of axis>()`.
There are VERY many `scale_` options.

Similar layers can be added for x and y axes, as well as other graph features like color and size.

Manipulate a continuous x axis

```
scale_x_continuous(breaks = , # use a vector to specify locations  
                  minor_breaks = , # also can be a vector  
                  n.breaks = , # can specify the number of breaks  
                  labels = , # change the labels on the breaks  
                  limits = , # set the upper and lower limits  
                  position = # "left", "right", "top", "bottom")
```

Manipulate a discrete x axis

```
scale_x_discrete(breaks = , # character vector of breaks
                  limits = , # set possible values for scale
                  drop = , # TRUE or FALSE to drop unused factor levels
                  labels = , # change the labels on the breaks
                  position = # "left", "right", "top", "bottom")
```


Fill

We can change the fill to represent a variable:

```
data %>%  
  ggplot(aes(x = variable1,  
             fill = variable2)) +  
  geom_()
```

or to be a color of choice:

```
data %>%  
  ggplot(aes(x = variable1)) +  
  geom_(fill = "my_color")
```

The difference is where the **fill** = is located. If it is in the `aes()`, then it will represent a variable. If it is not in the `aes()`, it will just change the look of the graph.

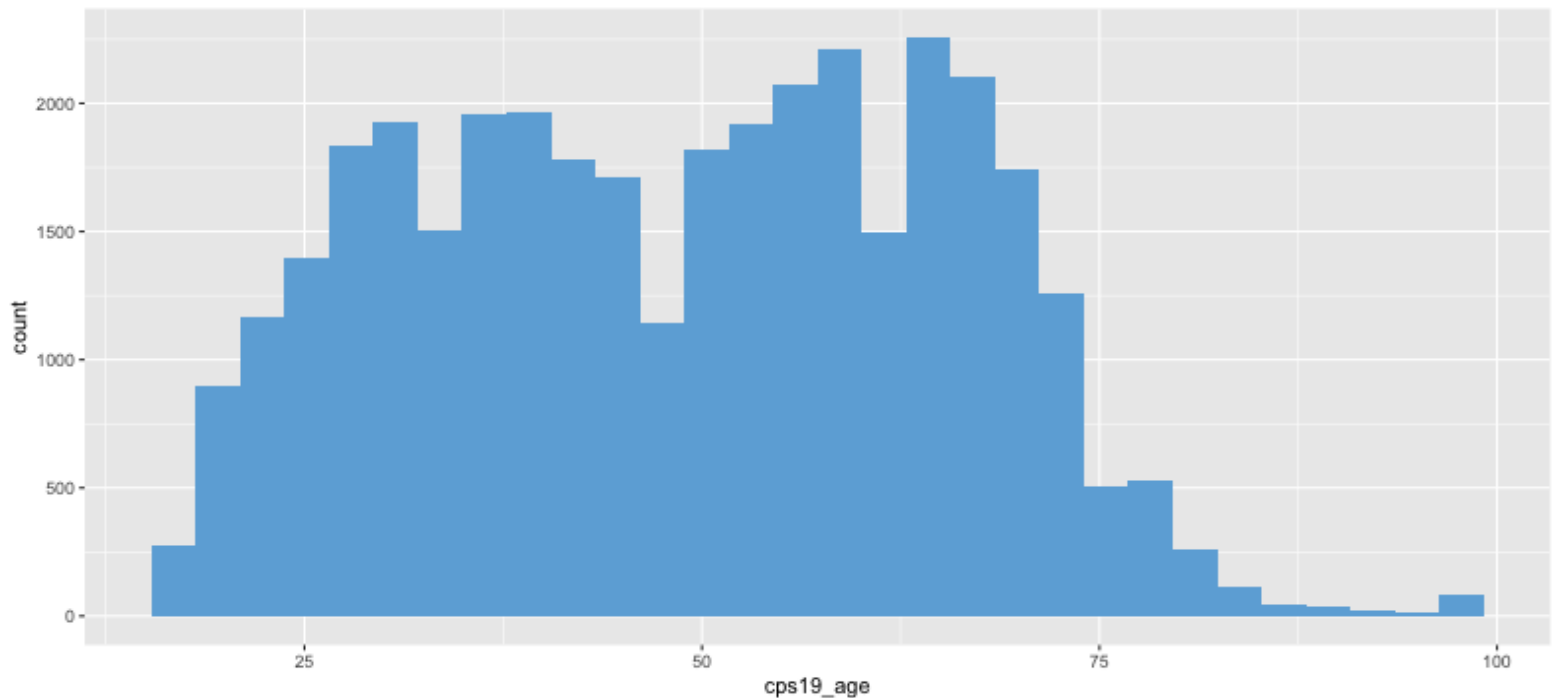
Fill to represent a variable

```
CES_data %>%  
  ggplot(aes(x = cps19_age,  
             fill = cps19_gender)) +  
  geom_histogram()
```



Changing fill to a specific color

```
CES_data %>%  
  ggplot(aes(x = cps19_age)) +  
  geom_histogram(fill = "#6DAEDB")
```



Color

For some geoms, you will need to change color rather than fill.

We can change the color to represent a variable:

```
data %>%  
  ggplot(aes(x = variable1,  
             color = variable2)) +  
  geom_()
```

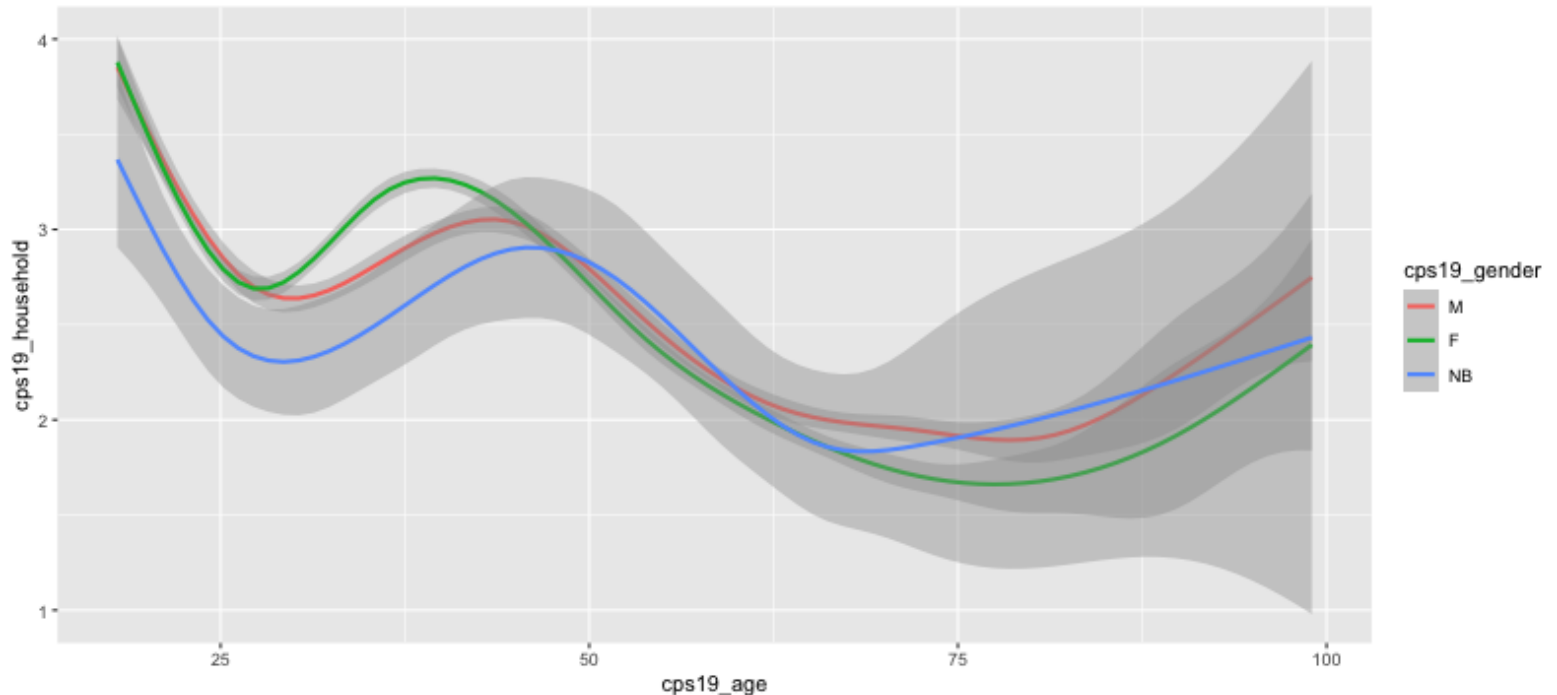
or to be a color of choice:

```
data %>%  
  ggplot(aes(x = variable1)) +  
  geom_(color = "my_color")
```

The difference is where the `color =` is located. If it is in the `aes()`, then it will represent a variable. If it is not in the `aes()`, it will just change the look of the graph.

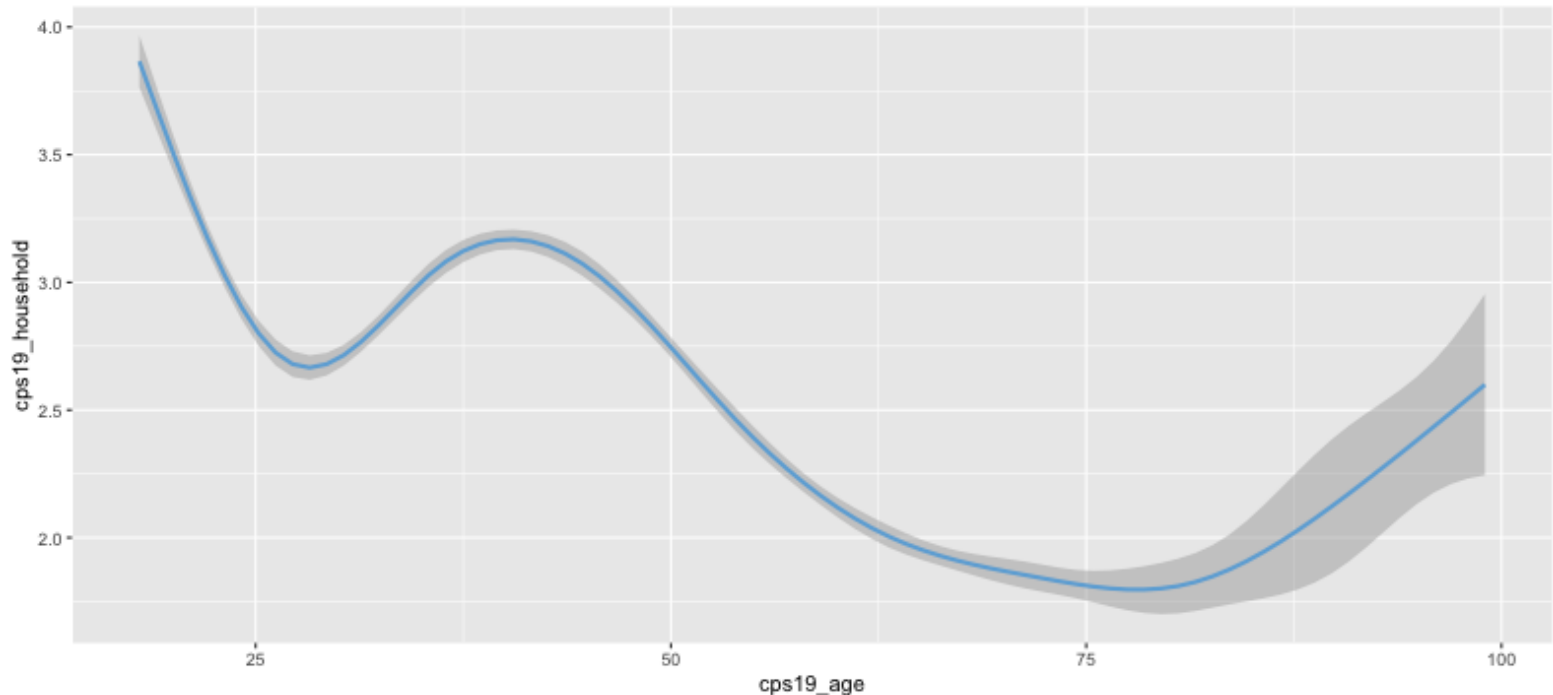
Color to represent a variable

```
CES_data %>%  
  ggplot(aes(x = cps19_age,  
             y = cps19_household,  
             color = cps19_gender)) +  
  geom_smooth()
```



Color for visual effect

```
CES_data %>%  
  ggplot(aes(x = cps19_age,  
             y = cps19_household)) +  
  geom_smooth(color = "#6DAEDB")
```



Size

We can change the size to represent a variable:

```
data %>%  
  ggplot(aes(x = variable1,  
             y = variable2,  
             size = variable3)) +  
  geom_()
```

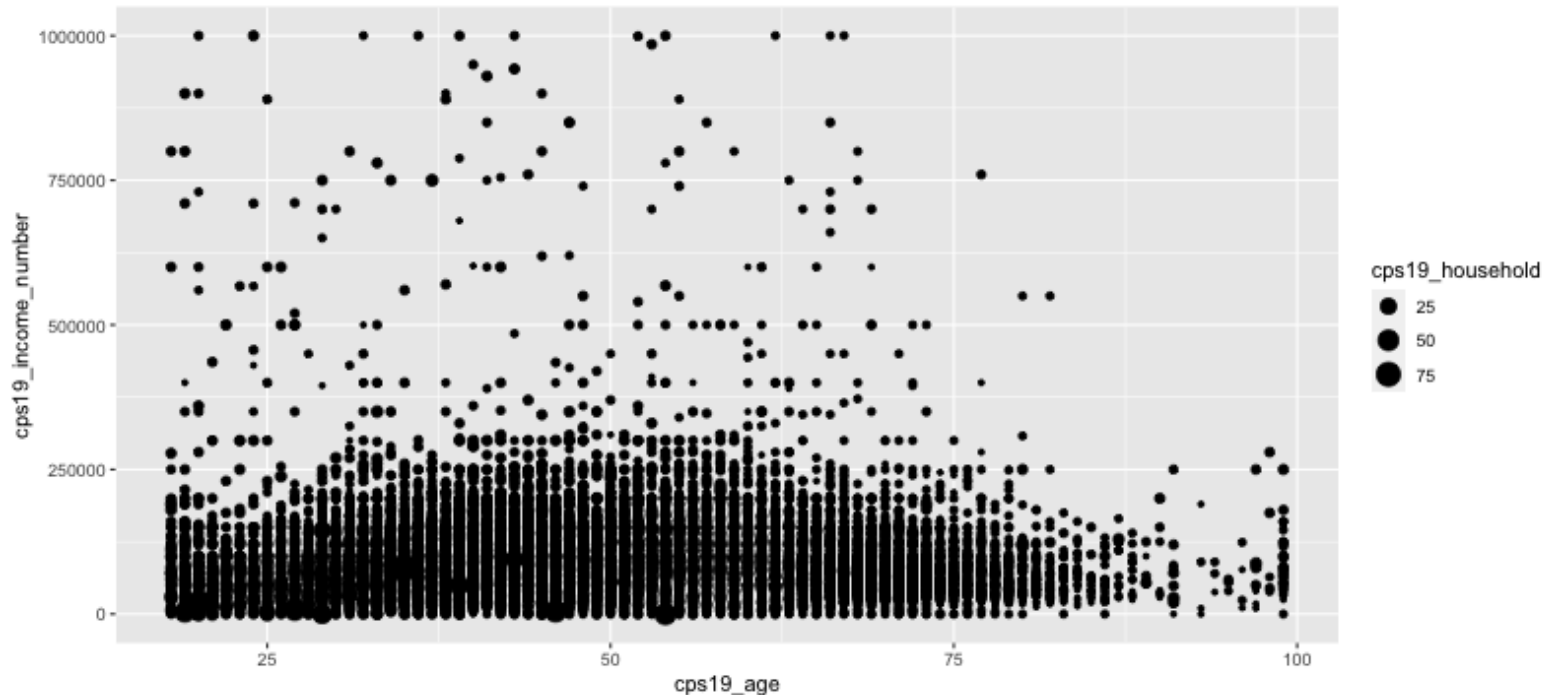
or to be a color of choice:

```
data %>%  
  ggplot(aes(x = variable1,  
             y = variable2)) +  
  geom_(size = "my_size")
```

The difference is where the **fill** = is located. If it is in the `aes()`, then it will represent a variable. If it is not in the `aes()`, it will just change the look of the graph.

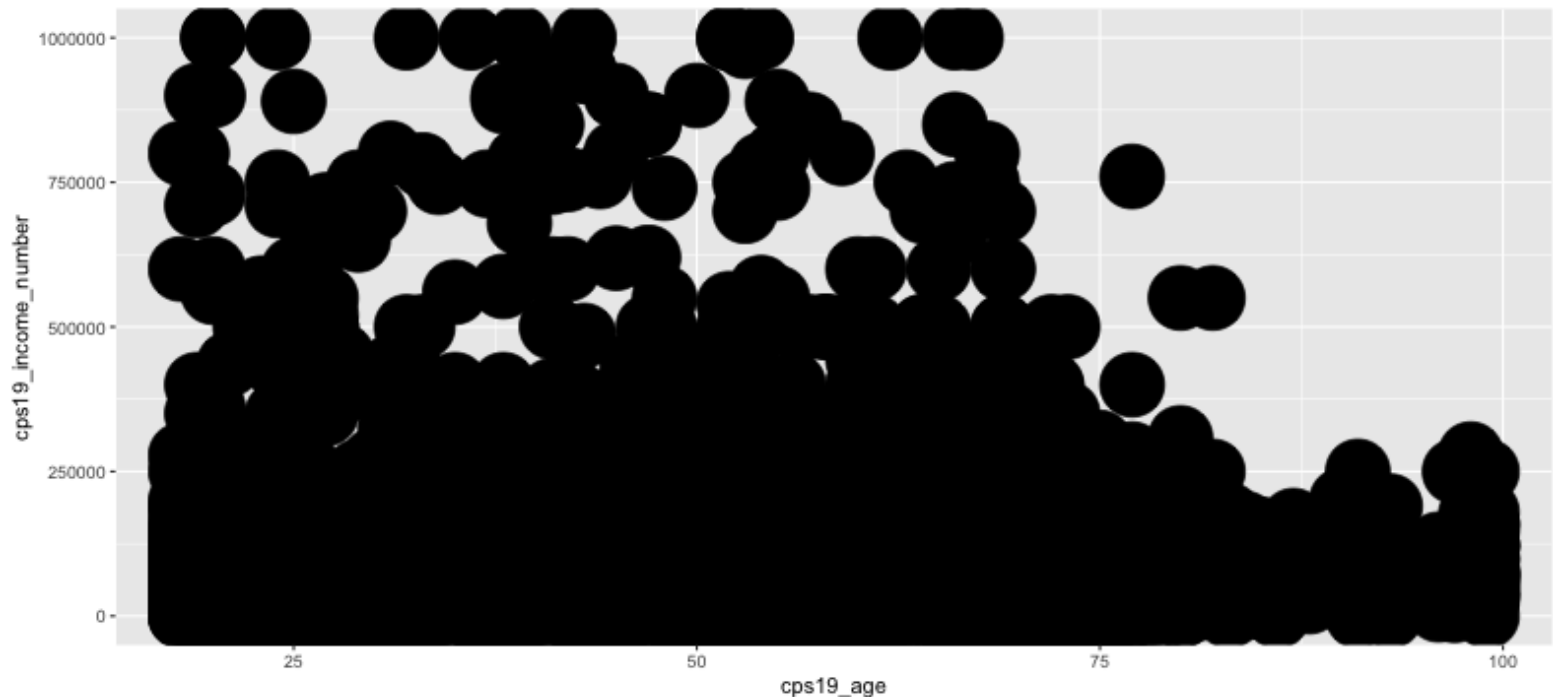
Size to represent a variable

```
CES_data %>%  
  ggplot(aes(x = cps19_age,  
             y = cps19_income_number,  
             size = cps19_household)) +  
  geom_point()
```



Size for visual effect

```
CES_data %>%  
  ggplot(aes(x = cps19_age,  
             y = cps19_income_number)) +  
  geom_point(size = 15)
```



Using multiple geoms

We can layer geoms on top of one another.

Geoms can either share their aes():

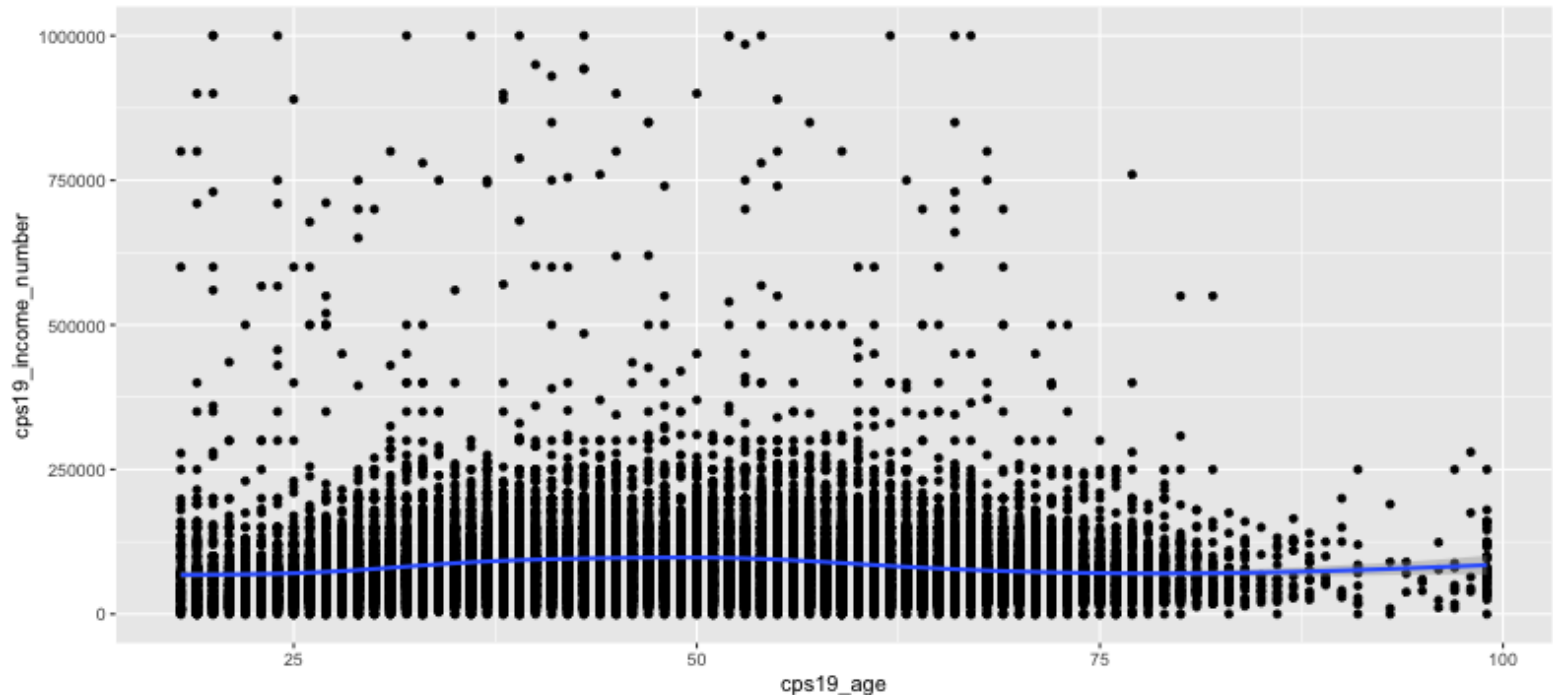
```
data %>%  
  ggplot(aes(x = variable1,  
             y = variable2)) +  
  geom_() +  
  geom_()
```

or they can have their own:

```
data %>%  
  ggplot() +  
  geom_(aes(x = variable1,  
            y = variable2)) +  
  geom_(aes(x = variable1,  
            y = variable3))
```

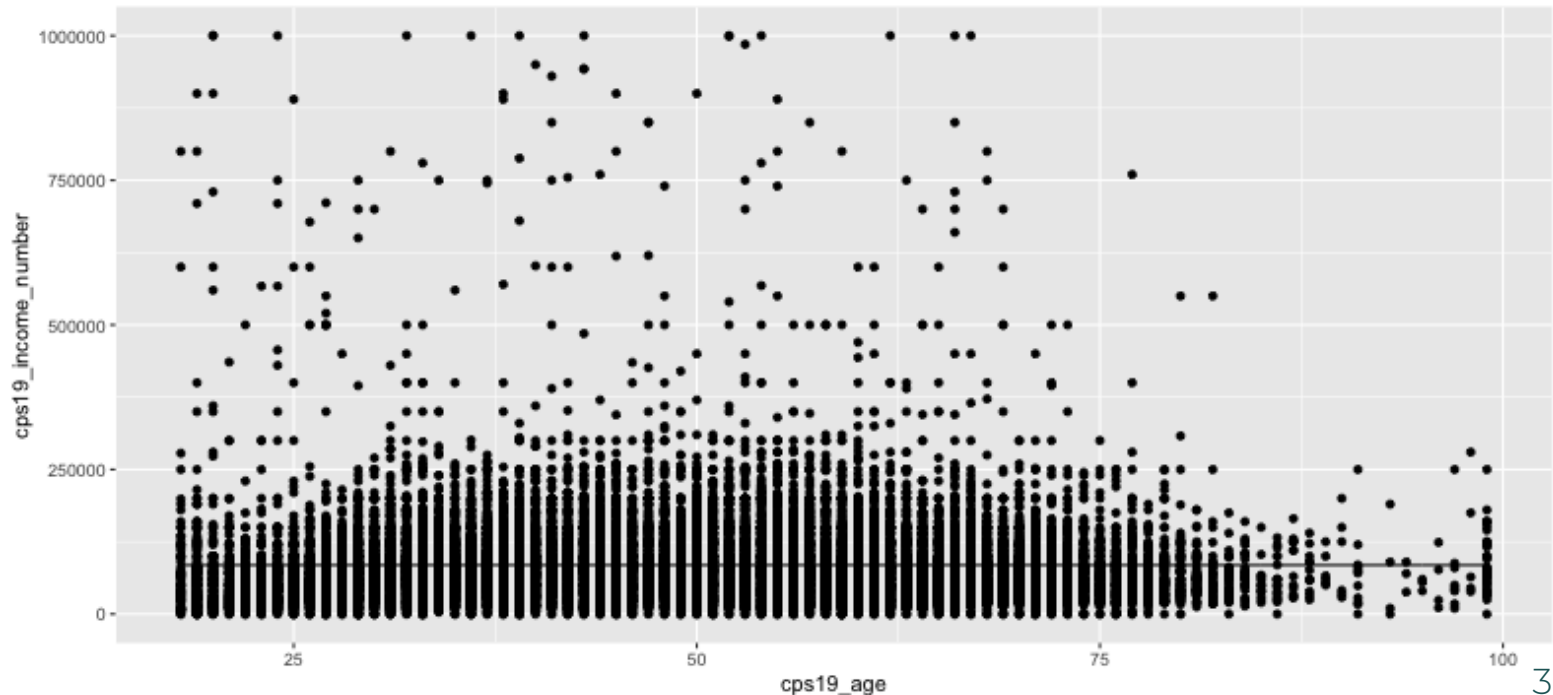
Geoms that share aesthetics

```
CES_data %>%  
  ggplot(aes(x = cps19_age,  
             y = cps19_income_number)) +  
    geom_point() +  
    geom_smooth()
```



Separate geom aesthetics

```
CES_data %>%  
  ggplot() +  
  geom_point(aes(x = cps19_age,  
                 y = cps19_income_number)) +  
  geom_line(aes(x = cps19_age,  
                y = mean(cps19_income_number, na.rm = TRUE)))
```



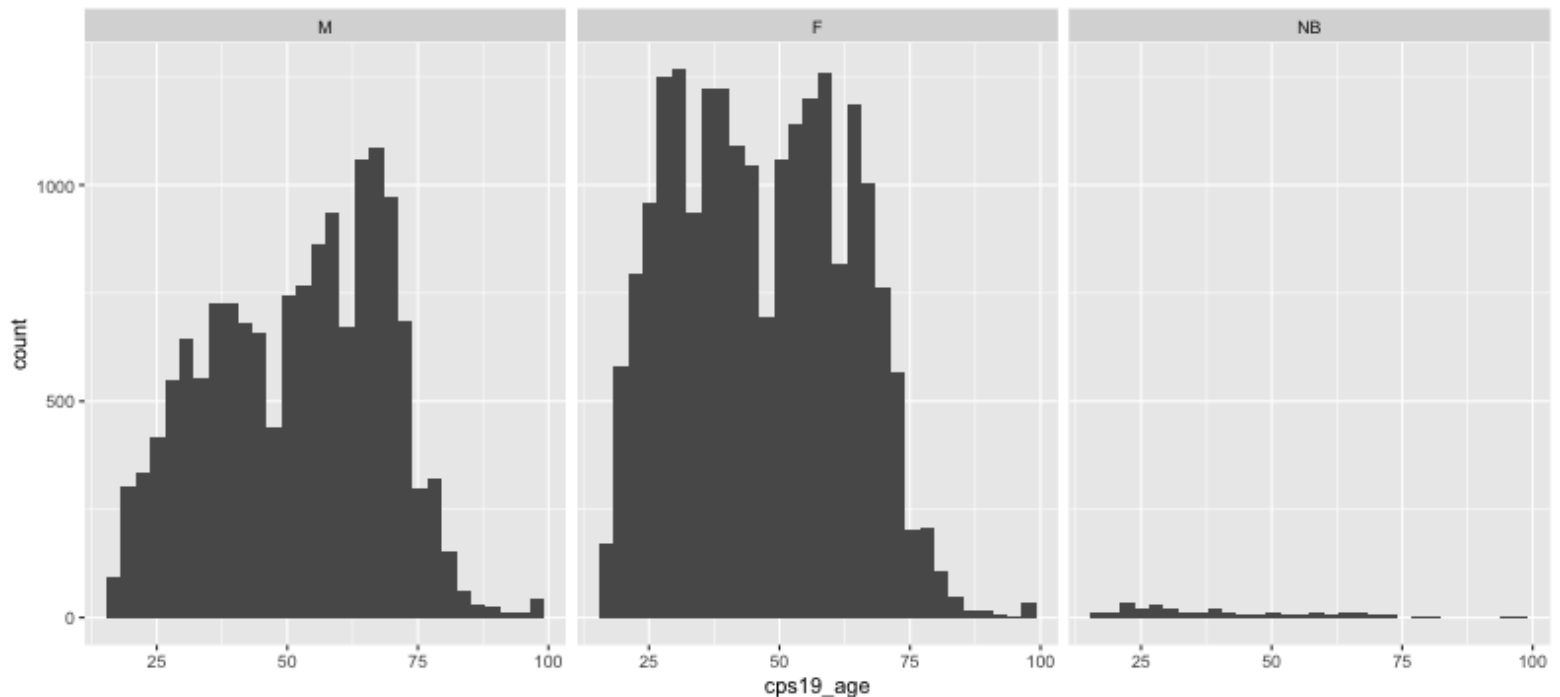
Facets

Facets give you side-by-side graphs for different categories.

```
facet_wrap(facets = "variables you want to facet by")  
facet_grid(facets = "variables that you want to facet by")
```

Facets

```
CES_data %>%  
  ggplot(aes(x = cps19_age)) +  
  geom_histogram() +  
  facet_wrap(facets = "cps19_gender")
```



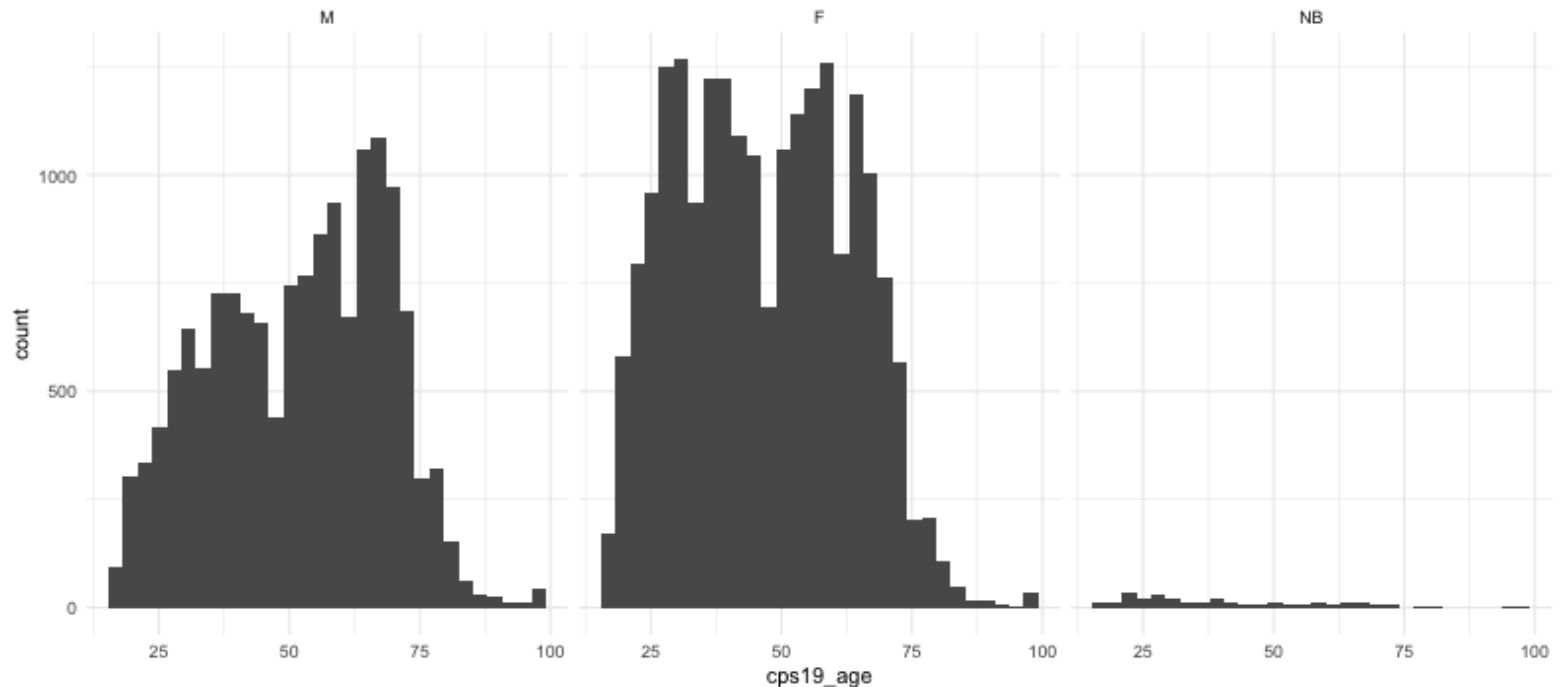
Themes

Themes are added at the end. They control the overall look.

```
theme_bw()  
theme_classic()  
theme_light()  
theme_minimal()
```

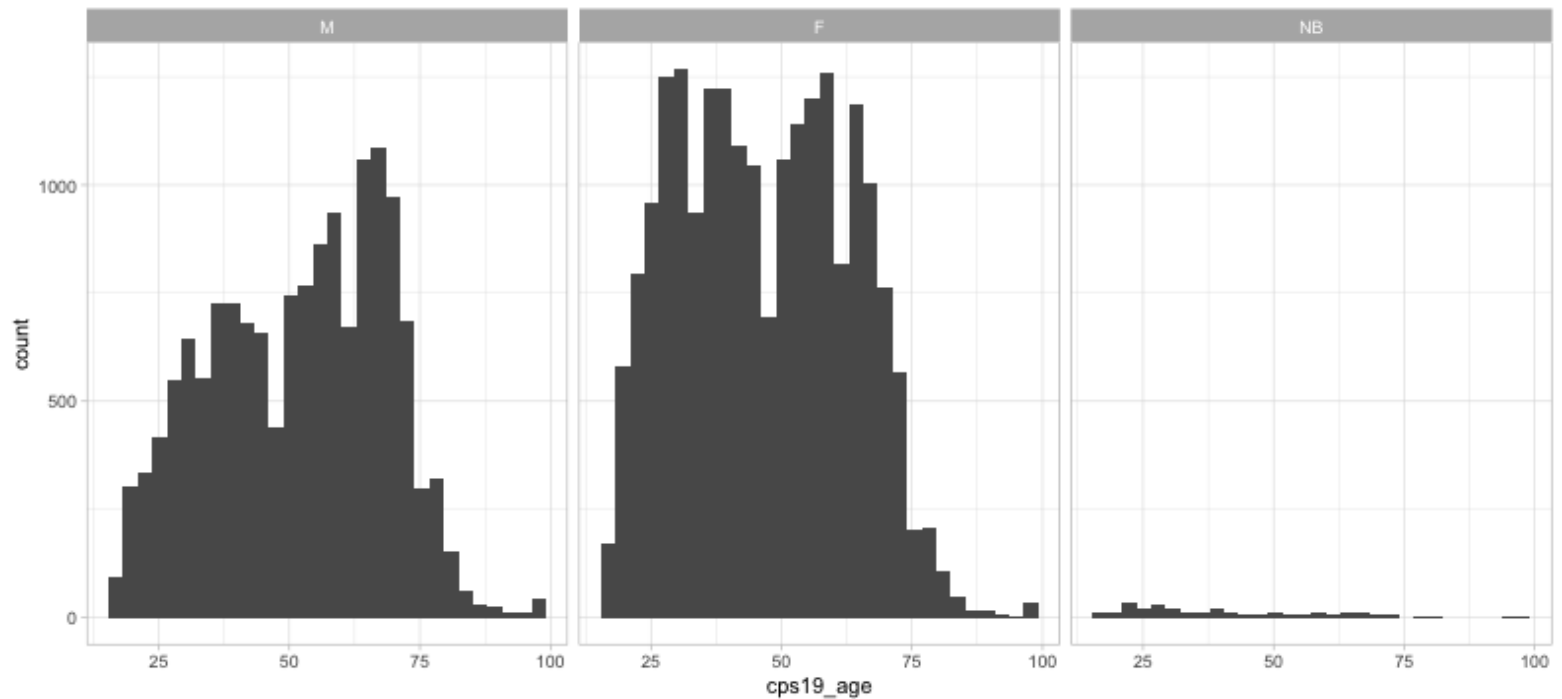
Themes

```
CES_data %>%  
  ggplot(aes(x = cps19_age)) +  
  geom_histogram() +  
  facet_wrap(facets = "cps19_gender") +  
  theme_minimal()
```



Themes

```
CES_data %>%  
  ggplot(aes(x = cps19_age)) +  
  geom_histogram() +  
  facet_wrap(facets = "cps19_gender") +  
  theme_light()
```

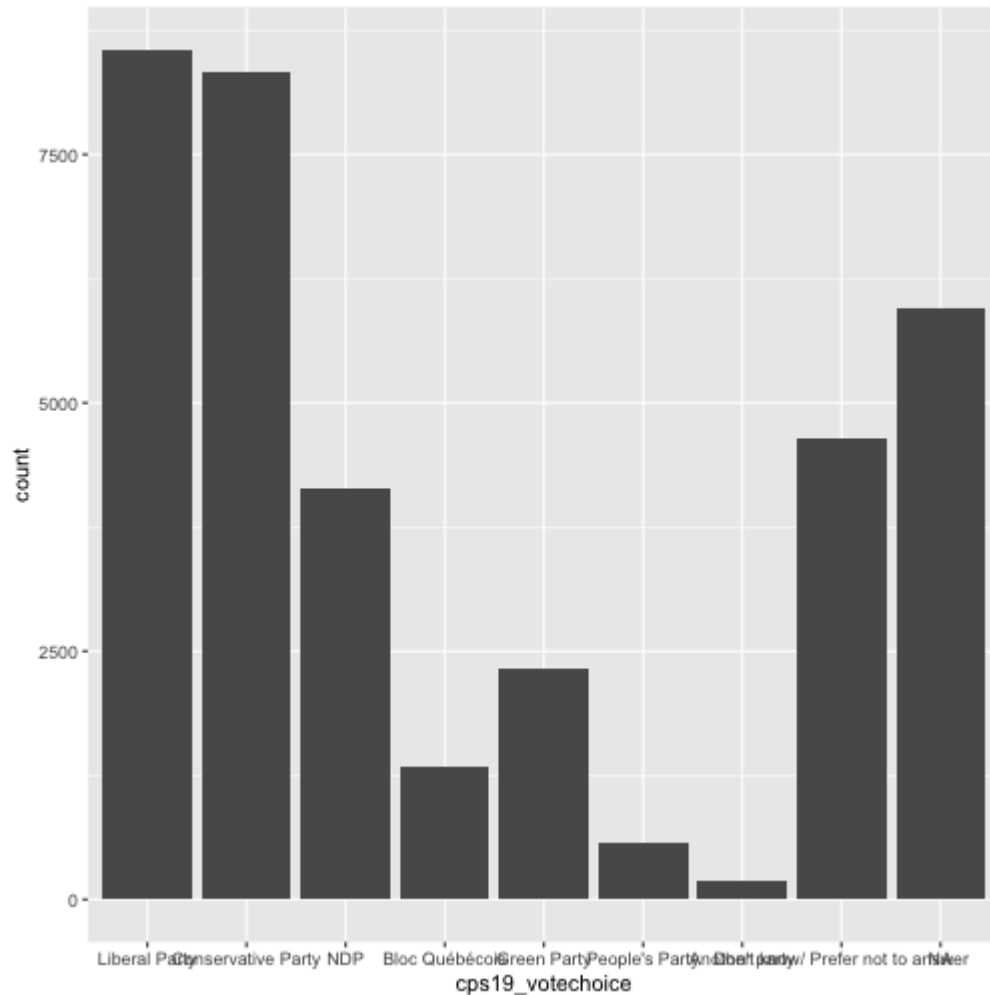


Example: Graphing CES data

We can make a bar graph representing the response to the question: "Which party do you think you will vote for?", named `cps19_votechoice`.

```
CES_data %>%  
  ggplot() +  
  geom_bar(aes(x = cps19_votechoice))
```

Bar graphs

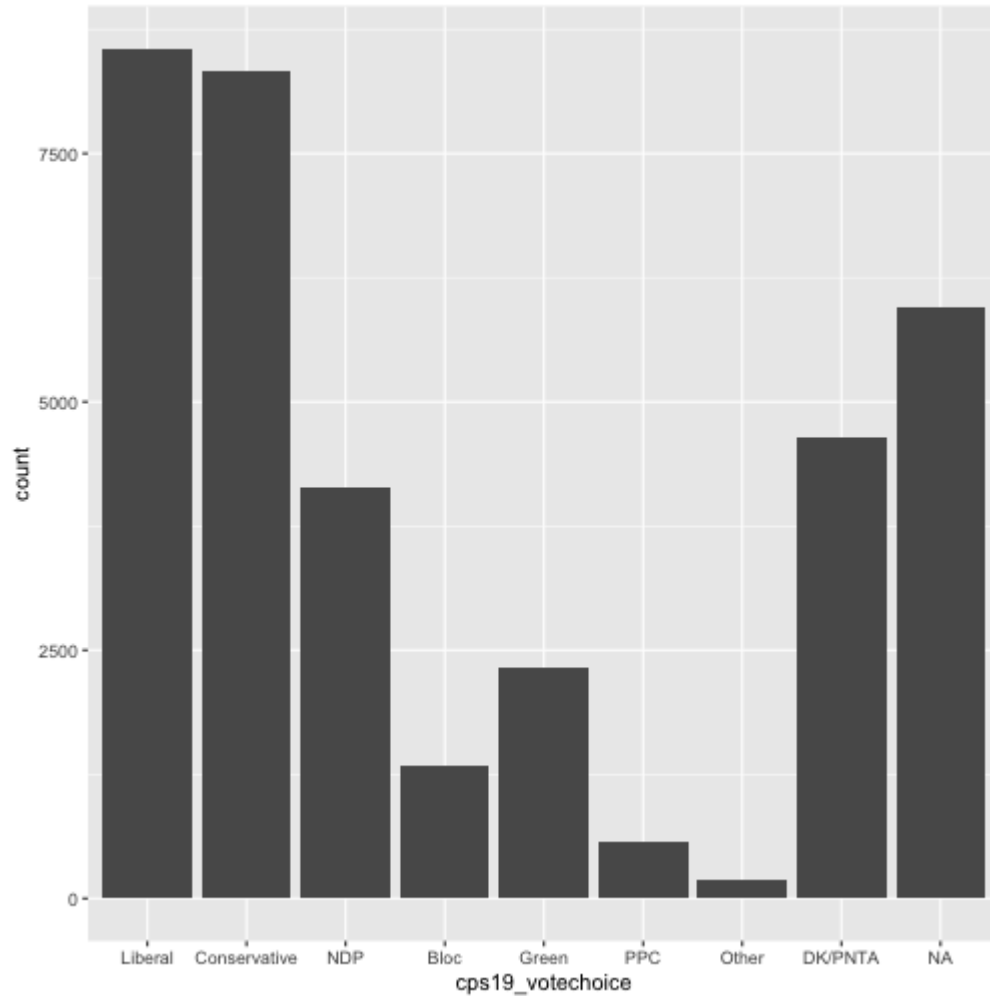


Bar graphs

You may want to use more short forms in the responses to make the graph more readable. To manipulate the axis labels, we use the `scale_x_discrete` function and specify what labels we want:

```
CES_data %>%  
  ggplot() +  
  geom_bar(aes(x = cps19_votechoice)) +  
  scale_x_discrete(labels = c(  
    "Liberal Party" = "Liberal",  
    "Conservative Party" = "Conservative",  
    "Bloc Québécois" = "Bloc",  
    "Green Party" = "Green",  
    "People's Party" = "PPC",  
    "Another party" = "Other",  
    "Don't know/ Prefer not to answer" = "DK/PNTA")  
  )
```

Bar graphs

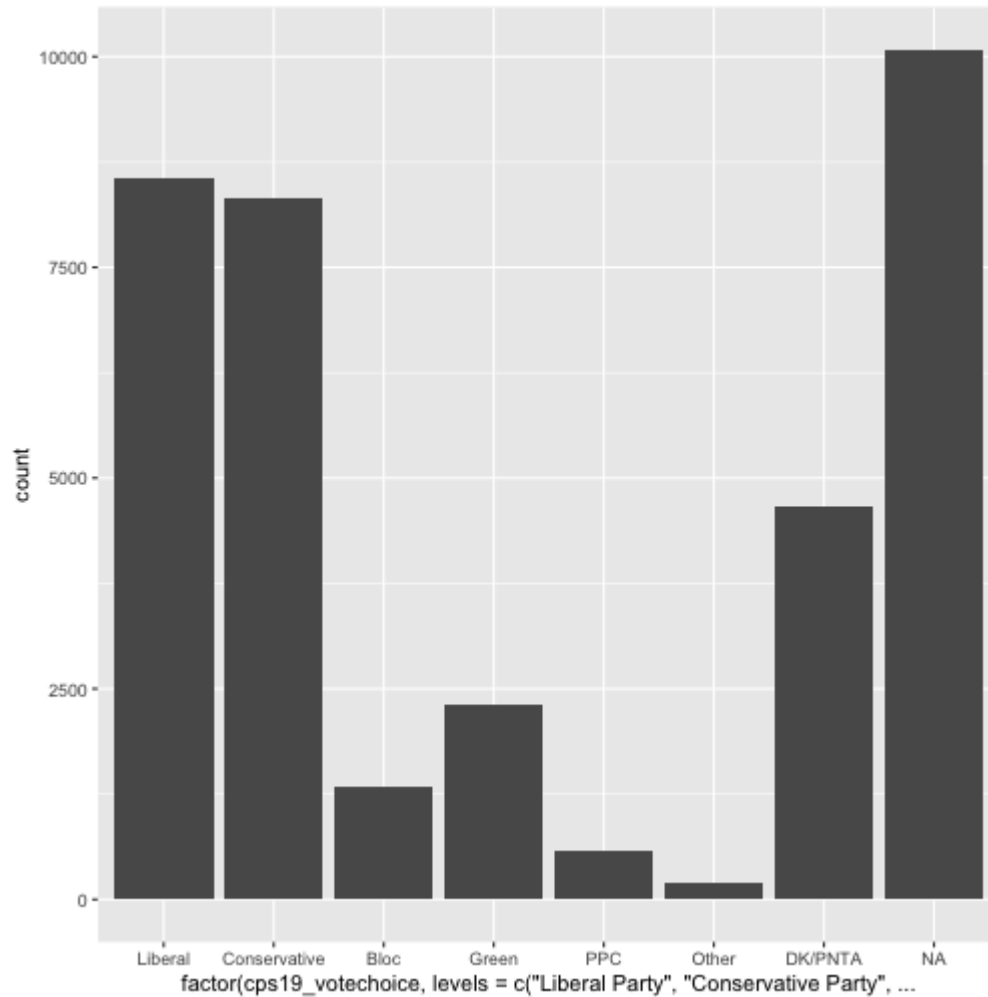


Bar graphs

We can also reorder bars from in a way that makes more sense. To do this, we take the variable and make it into a factor. Factors have a specific order, given in the **levels** argument:

```
CES_data %>%  
  ggplot() +  
  geom_bar(aes(x = factor(cps19_votechoice,  
                        levels = c("Liberal Party",  
                                   "Conservative Party",  
                                   "Bloc Québécois",  
                                   "Green Party",  
                                   "People's Party",  
                                   "Another party",  
                                   "Don't know/ Prefer not to answer"),  
  scale_x_discrete(labels = c(  
    "Liberal Party" = "Liberal",  
    "Conservative Party" = "Conservative",  
    "Bloc Québécois" = "Bloc",  
    "Green Party" = "Green",  
    "People's Party" = "PPC",  
    "Another party" = "Other",  
    "Don't know/ Prefer not to answer" = "DK/PNTA")  
  )
```

Bar graphs

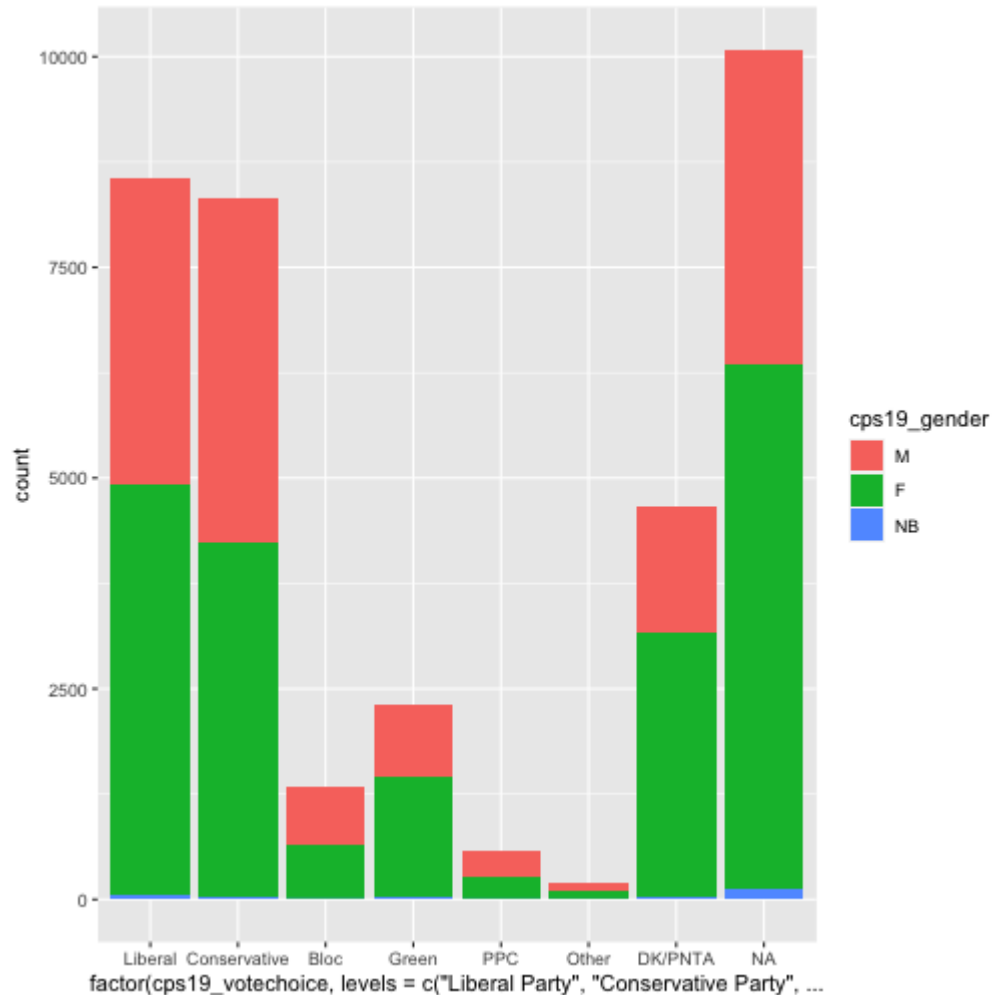


Bar graphs

What if we want to compare the voting intentions between genders? We can use the **fill** argument in the **aes()** function to do that:

```
CES_data %>%  
  ggplot() +  
  geom_bar(aes(x = factor(cps19_votechoice,  
                        levels = c("Liberal Party",  
                                   "Conservative Party",  
                                   "Bloc Québécois",  
                                   "Green Party",  
                                   "People's Party",  
                                   "Another party",  
                                   "Don't know/ Prefer not to answer"),  
              fill = cps19_gender)) +  
  scale_x_discrete(labels = c(  
    "Liberal Party" = "Liberal",  
    "Conservative Party" = "Conservative",  
    "Bloc Québécois" = "Bloc",  
    "Green Party" = "Green",  
    "People's Party" = "PPC",  
    "Another party" = "Other",  
    "Don't know/ Prefer not to answer" = "DK/PNTA"  
  ))
```


Bar graphs

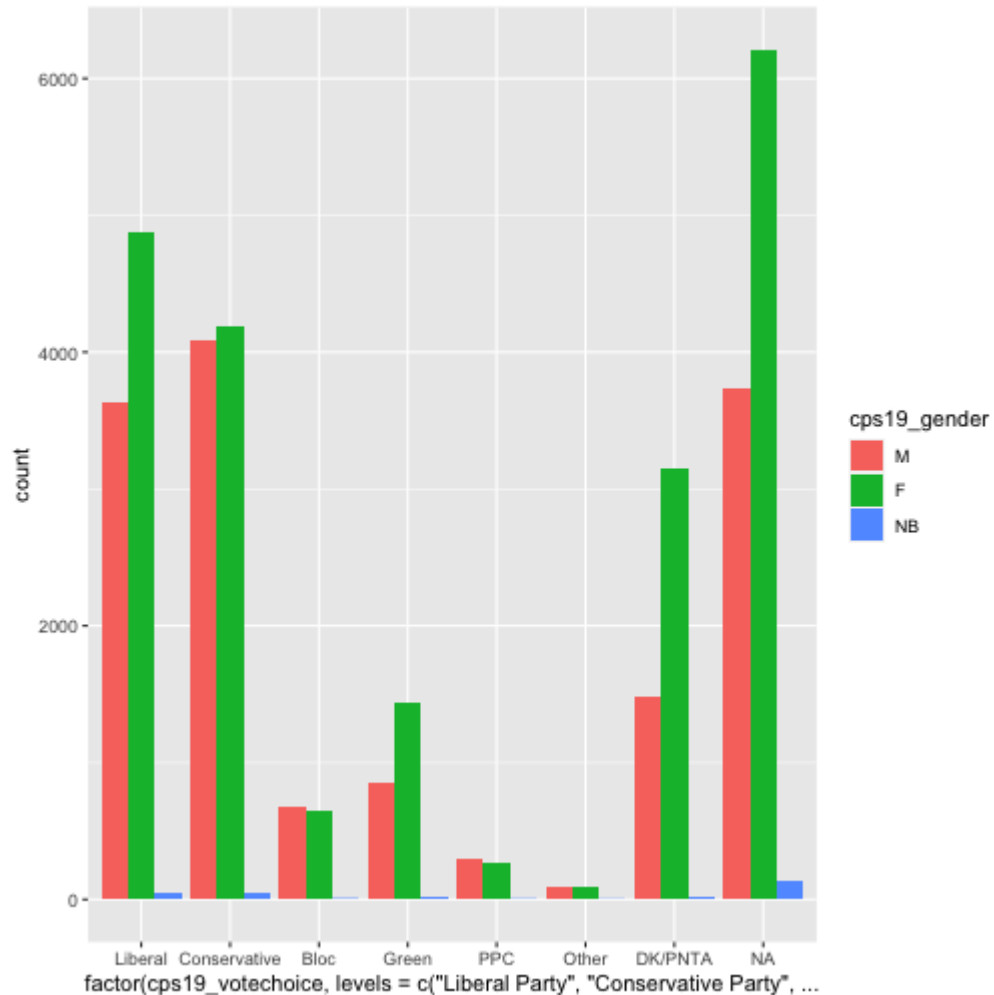


Bar graphs

If we don't want the bars to be stacked, we need to change the **position** argument in the **geom_bar()** function:

```
CES_data %>%
  ggplot() +
  geom_bar(aes(x = factor(cps19_votechoice,
                        levels = c("Liberal Party",
                                   "Conservative Party",
                                   "Bloc Québécois",
                                   "Green Party",
                                   "People's Party",
                                   "Another party",
                                   "Don't know/ Prefer not to answer"),
                        fill = cps19_gender),
            position = "dodge") +
  scale_x_discrete(labels = c(
    "Liberal Party" = "Liberal",
    "Conservative Party" = "Conservative",
    "Bloc Québécois" = "Bloc",
    "Green Party" = "Green",
    "People's Party" = "PPC",
    "Another party" = "Other",
    "Don't know/ Prefer not to answer" = "DK/PNTA")
```

Bar graphs

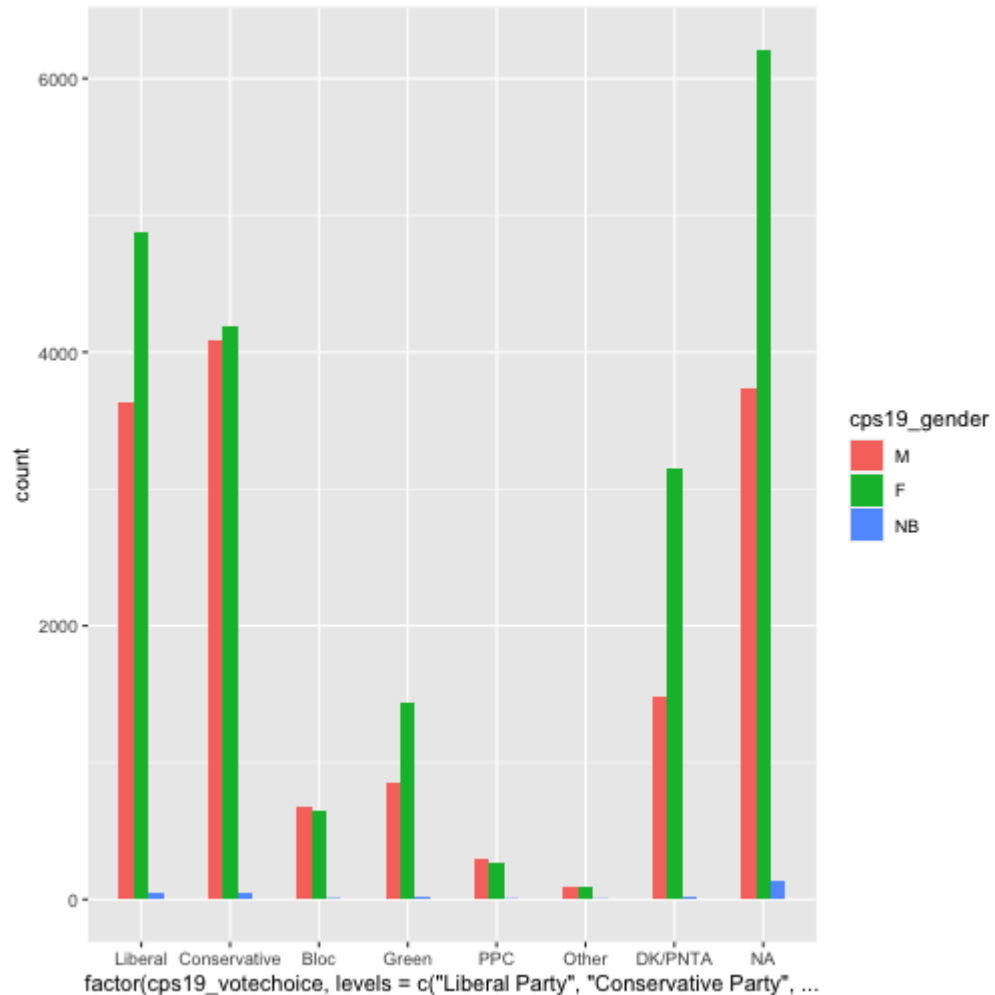


Bar graphs

We can change the widths of the bars as well:

```
CES_data %>%
  ggplot() +
  geom_bar(aes(x = factor(cps19_votechoice,
                        levels = c("Liberal Party",
                                "Conservative Party",
                                "Bloc Québécois",
                                "Green Party",
                                "People's Party",
                                "Another party",
                                "Don't know/ Prefer not to answer"),
                        fill = cps19_gender),
            position = "dodge",
            width = 0.5) +
  scale_x_discrete(labels = c(
    "Liberal Party" = "Liberal",
    "Conservative Party" = "Conservative",
    "Bloc Québécois" = "Bloc",
    "Green Party" = "Green",
    "People's Party" = "PPC",
    "Another party" = "Other",
    "Don't know/ Prefer not to answer" = "DK/PNTA")
```

Bar graphs



Histograms

We can make a histogram representing the response to the question: "How do you feel about the federal political parties below? Set the slider to a number from 0 to 100, where 0 means you really dislike the party and 100 means you really like the party." and the Conservative Party, named `cps19_party_rating_24`.

```
CES_data %>%  
  ggplot() +  
  geom_histogram(aes(x = cps19_party_rating_24))
```

Histograms

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.  
## Warning: Removed 2659 rows containing non-finite values (stat_bin).
```

Histograms

The histogram splits the range of values for Conservative Party rating into 30 bins automatically, but what if we want a different number of bins? We can change the **bins** argument in the **geom_histogram()** function:

```
CES_data %>%  
  ggplot() +  
  geom_histogram(aes(x = cps19_party_rating_24),  
                 bins = 10)
```


Histograms

```
## Warning: Removed 2659 rows containing non-finite values (stat_bin).
```

Histograms

If we want to look at distributions of a variable in different groups, we can use something called faceting. To show what the Conservative Party ratings look like across different views on education spending, we can add the `facet_wrap` function:

```
CES_data %>%  
  ggplot() +  
  geom_histogram(aes(x = cps19_party_rating_24),  
                 bins = 10) +  
  facet_wrap(facets = "cps19_spend_educ")
```

Histograms

```
## Warning: Removed 2659 rows containing non-finite values (stat_bin).
```

Histograms

We can use the `nrow` arguments to say how many rows we want the facets to form:

```
CES_data %>%  
  ggplot() +  
  geom_histogram(aes(x = cps19_party_rating_24),  
                 bins = 10) +  
  facet_wrap(facets = "cps19_spend_educ",  
            nrow = 1)
```

Histograms

```
## Warning: Removed 2659 rows containing non-finite values (stat_bin).
```

Histograms

The order of the facets could be better. We use the same **factor** and **levels** method as before:

```
CES_data %>%  
  ggplot() +  
  geom_histogram(aes(x = cps19_party_rating_24),  
                 bins = 10) +  
  facet_wrap(~factor(cps19_spend_educ,  
                    levels = c("Spend less",  
                               "Spend about the same as now",  
                               "Spend more",  
                               "Don't know/ Prefer not to answer")),  
            nrow = 1)
```

Histograms

```
## Warning: Removed 2659 rows containing non-finite values (stat_bin).
```

Histograms

For any graph, we probably want better labels than the variable names. We add the `labels()` function to specific labels for the x-axis, the y-axis, and the title:

```
CES_data %>%  
  ggplot() +  
  geom_histogram(aes(x = cps19_party_rating_24),  
                 bins = 10) +  
  facet_wrap(~factor(cps19_spend_educ,  
                    levels = c("Spend less",  
                               "Spend about the same as now",  
                               "Spend more",  
                               "Don't know/ Prefer not to answer")),  
            nrow = 1) +  
  labs(x = "Conservative Party rating",  
       y = "Count",  
       title = "Views on education spending and the Conservative Party")
```


Histograms

```
## Warning: Removed 2659 rows containing non-finite values (stat_bin).
```

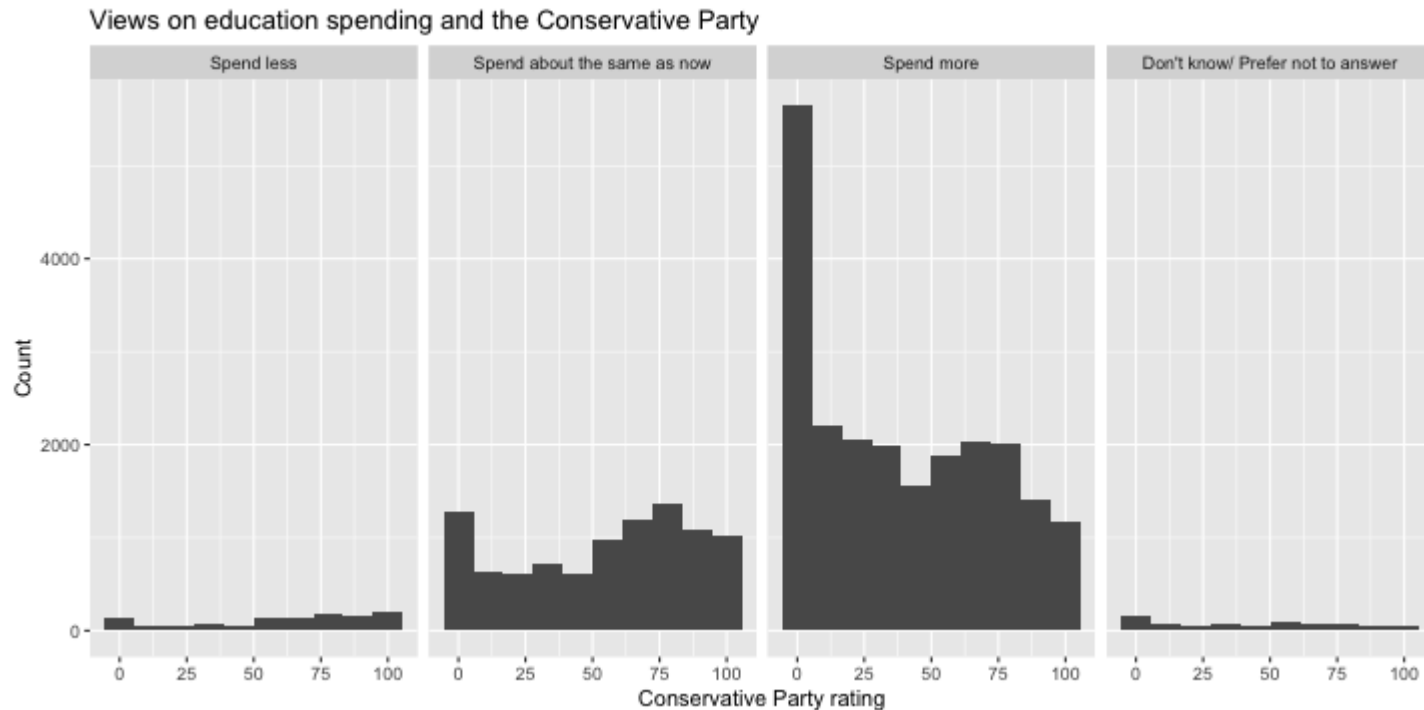
Histograms

We can widen the graph by editing the code chunk, specifying `fig.height` and `fig.width`:

```
CES_data %>%  
  ggplot() +  
  geom_histogram(aes(x = cps19_party_rating_24),  
                 bins = 10) +  
  facet_wrap(~factor(cps19_spend_educ,  
                    levels = c("Spend less",  
                               "Spend about the same as now",  
                               "Spend more",  
                               "Don't know/ Prefer not to answer")),  
            nrow = 1) +  
  labs(x = "Conservative Party rating",  
       y = "Count",  
       title = "Views on education spending and the Conservative Party")
```

Histograms

Warning: Removed 2659 rows containing non-finite values (stat_bin).

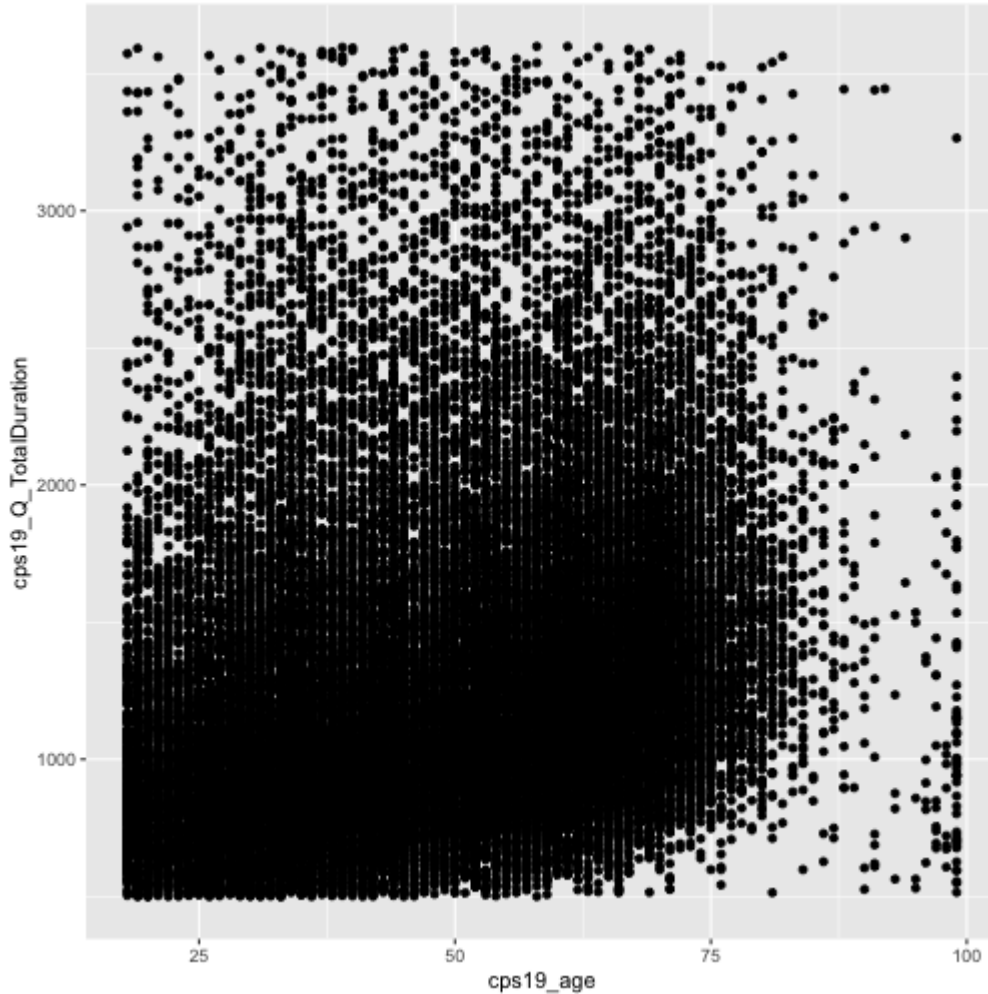


Scatterplots

We can make a scatterplot representing the relationship between the ages of the survey-takers and the time they spent on the survey, named `cps19_age` and `cps19_Q_TotalDuration`, using `geom_point()`:

```
CES_data %>%  
  ggplot() +  
  geom_point(aes(x = cps19_age,  
                 y = cps19_Q_TotalDuration))
```

Scatterplots



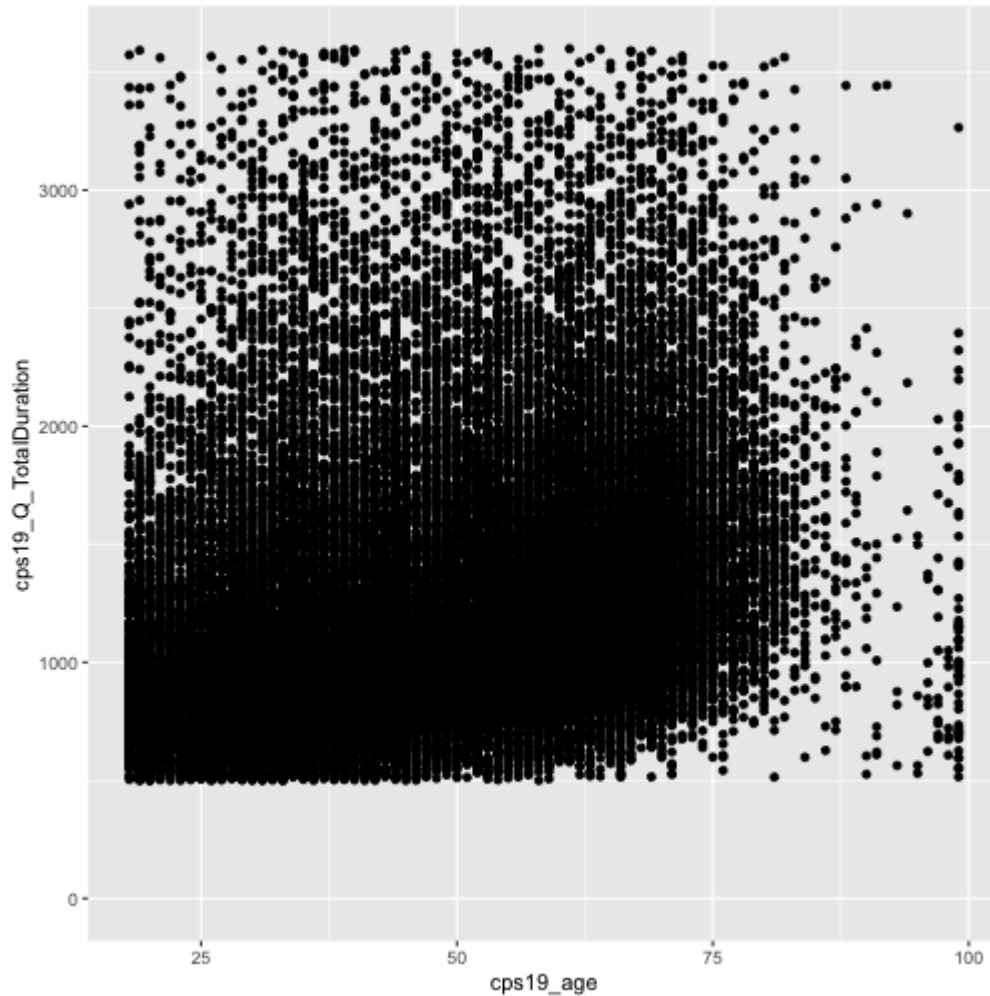
Scatterplots

There are some very large values for time spent on survey that makes it hard to see the rest. We can look at only the values in between 0 seconds and 3600 seconds, or 1 hour. Those that took longer are considered to be 'inattentive'.

One way to do this is to set limits on the axis using `scale_y_continuous()`:

```
CES_data %>%  
  ggplot() +  
  geom_point(aes(x = cps19_age,  
                 y = cps19_Q_TotalDuration)) +  
  scale_y_continuous(limits = c(0,3600))
```

Scatterplots



Scatterplots

Many points sitting exactly on top of each other, like what's happening with age, makes it hard to read the graph. If we add the argument `position = "jitter"` to the `geom_point()` function, ggplot will slightly separate points that are in exactly the same spot:

```
CES_data %>%  
  ggplot() +  
  geom_point(aes(x = cps19_age,  
                 y = cps19_Q_TotalDuration),  
             position = "jitter") +  
  scale_y_continuous(limits = c(0,3600))
```


Scatterplots

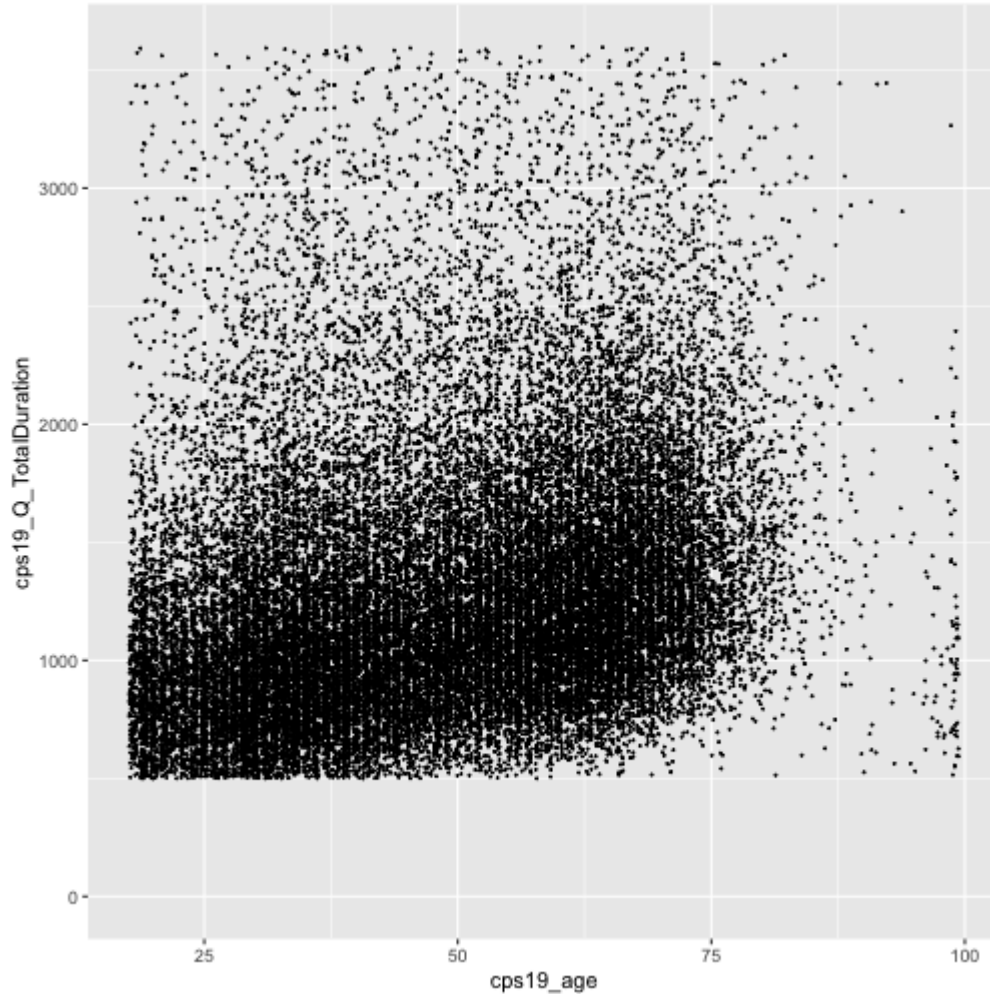
Many points sitting exactly on top of each other, like what's happening with age, makes it hard to read the graph. If we add the argument `position = "jitter"` to the `geom_point()` function, ggplot will slightly separate points that are in exactly the same spot:

Scatterplots

Now it's just formed a cloud. To get separation, we can decrease the size of the individual points with the **size** argument in **geom_point()**:

```
CES_data %>%  
  ggplot() +  
  geom_point(aes(x = cps19_age,  
                 y = cps19_Q_TotalDuration),  
            position = "jitter",  
            size = 0.1) +  
  scale_y_continuous(limits = c(0,3600))
```

Scatterplots

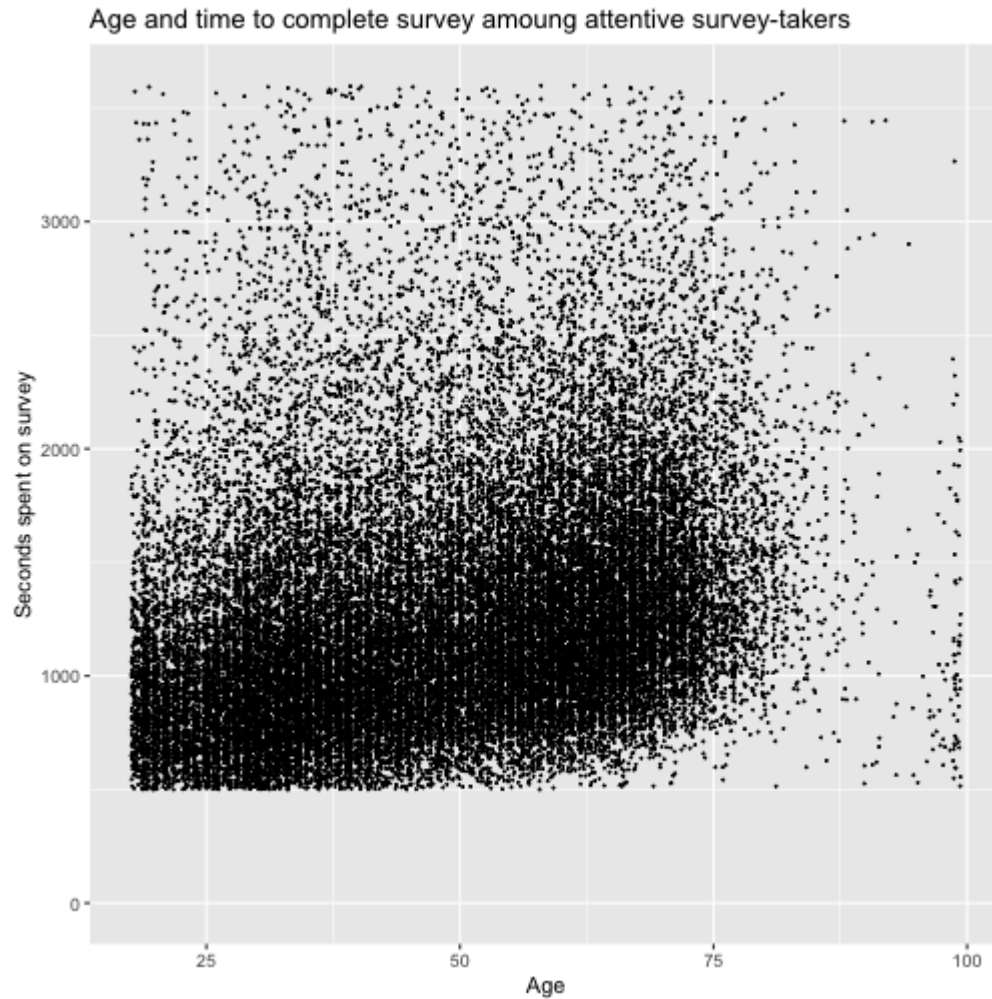


Scatterplots

Again, we can add labels:

```
CES_data %>%  
  ggplot() +  
  geom_point(aes(x = cps19_age,  
                 y = cps19_Q_TotalDuration),  
            position = "jitter",  
            size = 0.1) +  
  scale_y_continuous(limits = c(0,3600)) +  
  labs(x = "Age",  
       y = "Seconds spent on survey",  
       title = "Age and time to complete survey among attentive survey-")
```

Scatterplots



Exercises

Exercises

Take your:

1. barplots,
2. histograms, and
3. scatterplot from before

and customize them. Try to add each different customization to at least one plot.

Any questions?