Visualization for Data Science in R

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Data Matters 2019

https://github.com/amzoss/RVis-DM2019

Objectives/Outline

Day 1: Static visualizations

- Visualization and data science
- Basic ggplot2 syntax
- Basics of geoms and aes
- Manipulating data
- Categorical variables
- Advanced topics: mapping, saving charts out

Day 2: Interactivity

- Simple interactive plots
- Arranging charts into dashboards
- Incorporating Shiny elements into documents, dashboards
- Advanced topics: full Shiny apps

Set up environment

- R
- RStudio
- packages

Packages:

- tidyverse
- maps
- mapproj
- sf
- knitr
- plotly
- flexdashboard
- shiny

Get workshop files

URL: https://github.com/amzoss/RVis-DM2019

With Git installed

In RStudio:

- Project → New project
- Version Control
- Git
  - Paste in GitHub URL
  - Project directory name: **RVis-DM2019**
  - Subdirectory: you choose
- Create Project

Without Git installed

- Click green button to download ZIP
- Unzip files on your laptop

In RStudio:

- Project → New project…
- Existing directory
- Select unzipped folder
- Create Project

What does it mean to represent data visually? Why do it?

Math is hard

1		2		3		4	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

Almost identical summary statistics:

x & y mean

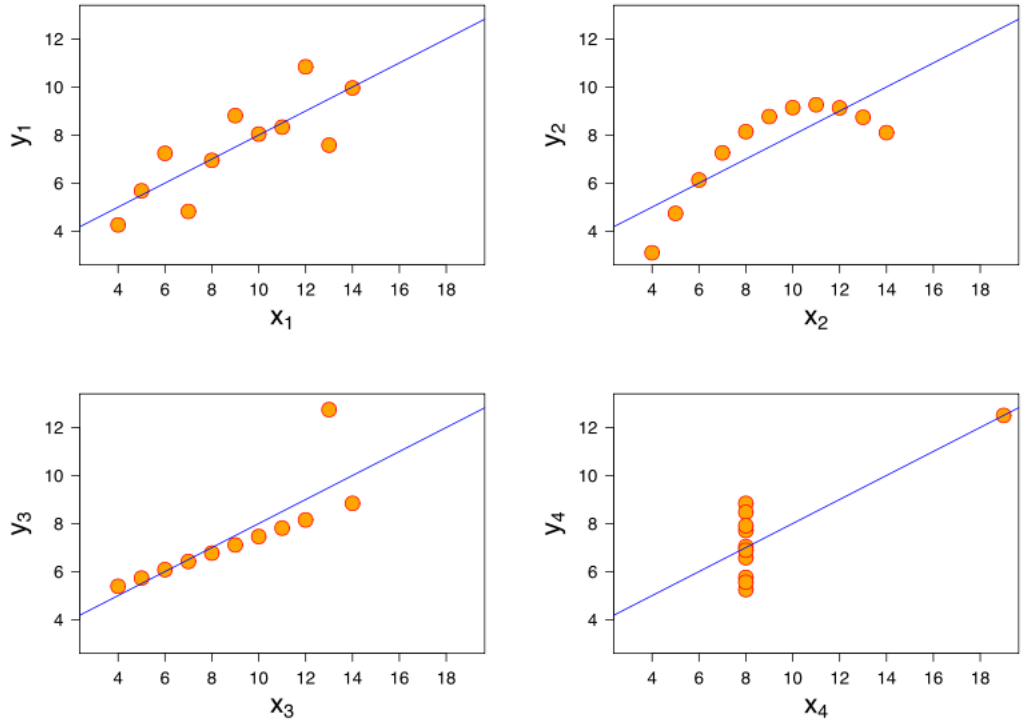
x & y variance

x-y correlation

x-y linear regression

https://en.wikipedia.org/wiki/Anscombe%27s_quartet

Shapes are much easier



Anscombe's Quartet

http://en.wikipedia.org/wiki/Anscombe%27s_quartet

Why visualize in R?

- Quickly explore data
- Save time switching to another tool
- Use charts to inspire new analyses and vice versa
- Reproducibility

Why care about reproducibility?

- Open science makes review easier
- Increasingly a requirement
- Saves you a lot of time trying to figure out what you did last time!

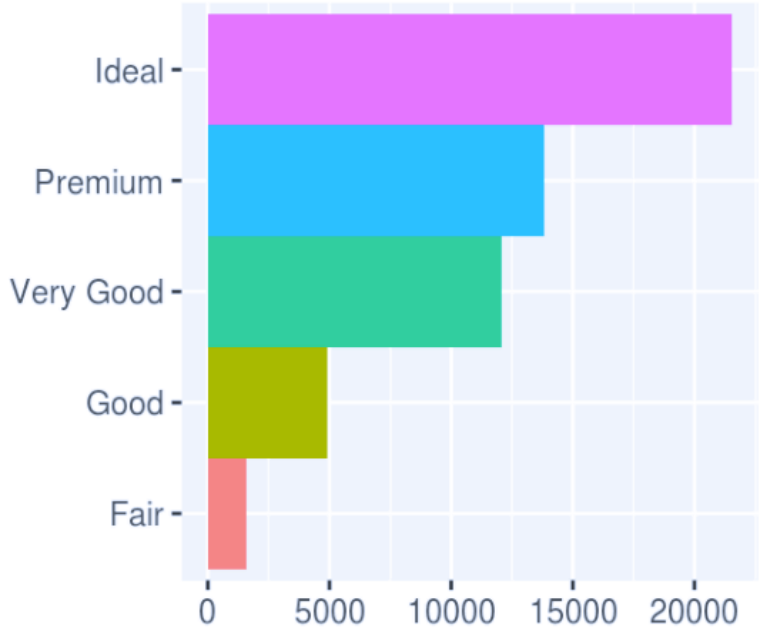
*“Your closest collaborator is **you** six months ago, but you don’t reply to emails.”*

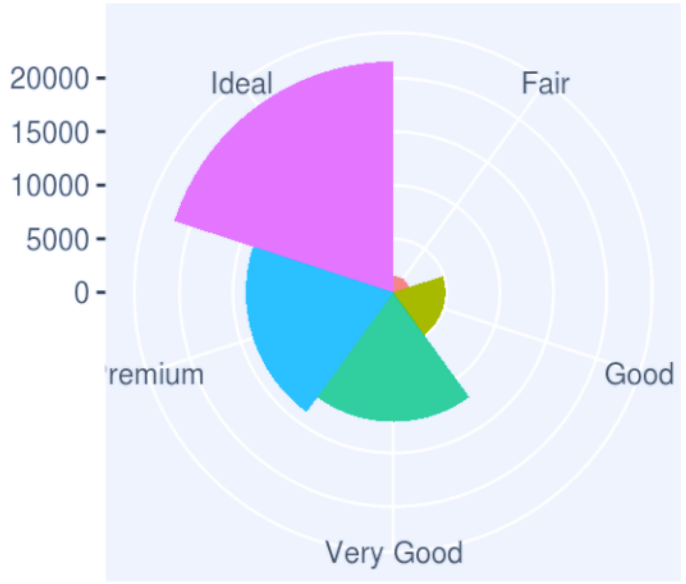
- Mark Holder

ggplot2

What is ggplot2?

an R package designed to create plots based on a theory of the grammar of graphics.





http://r4ds.had.co.nz/data-visualisation.html

Grammar of graphics

1. DATA: a set of data operations that create variables from datasets
2. TRANS: variable transformations (e.g., rank)
3. SCALE: scale transformations (e.g., log)
4. COORD: a coordinate system (e.g., polar)
5. ELEMENT: graphs (e.g., points) and their aesthetic attributes (e.g., color)
6. GUIDE: one or more guides (axes, legends, etc.).

Wilkinson, Leland. (2005). *The grammar of graphics (2nd ed)*. New York: Springer.

Why ggplot2 instead of base R?

- nice defaults
- easy faceting
- (arguably) more natural syntax
- can switch chart types more easily

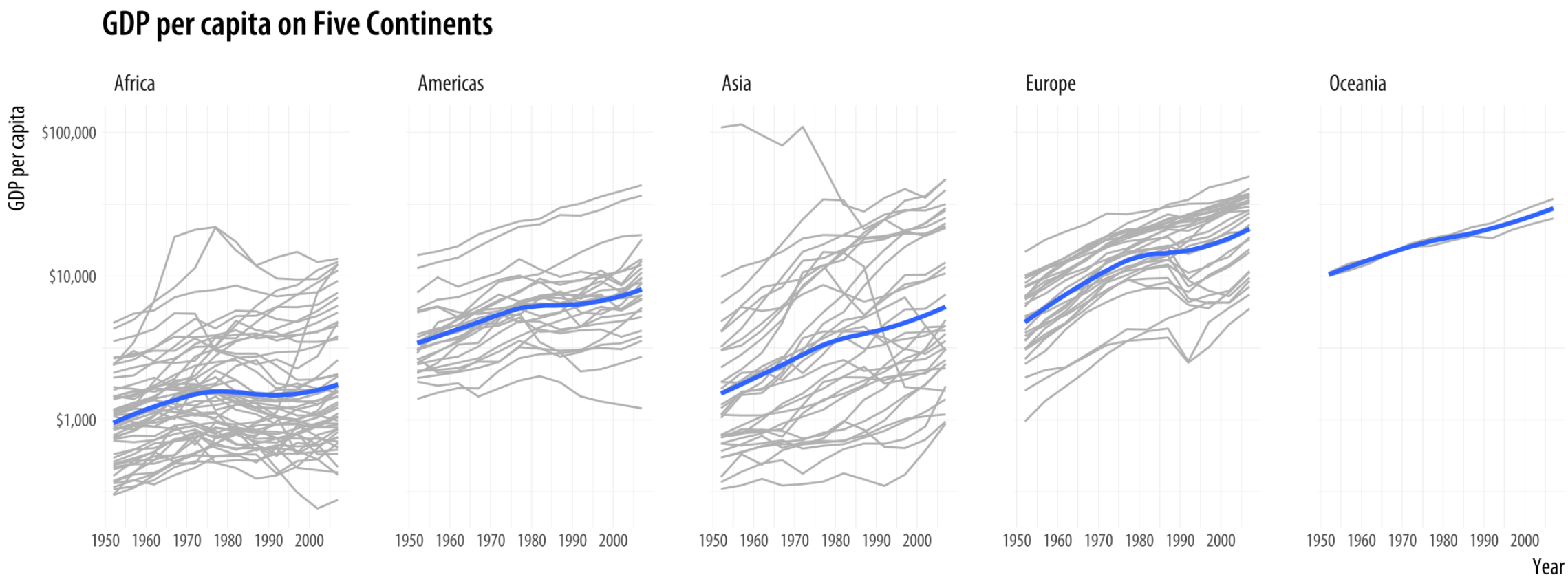
“Why I use ggplot2”, David Robinson
http://varianceexplained.org/r/why-I-use-ggplot2/

R vs. Excel, Tableau, etc.

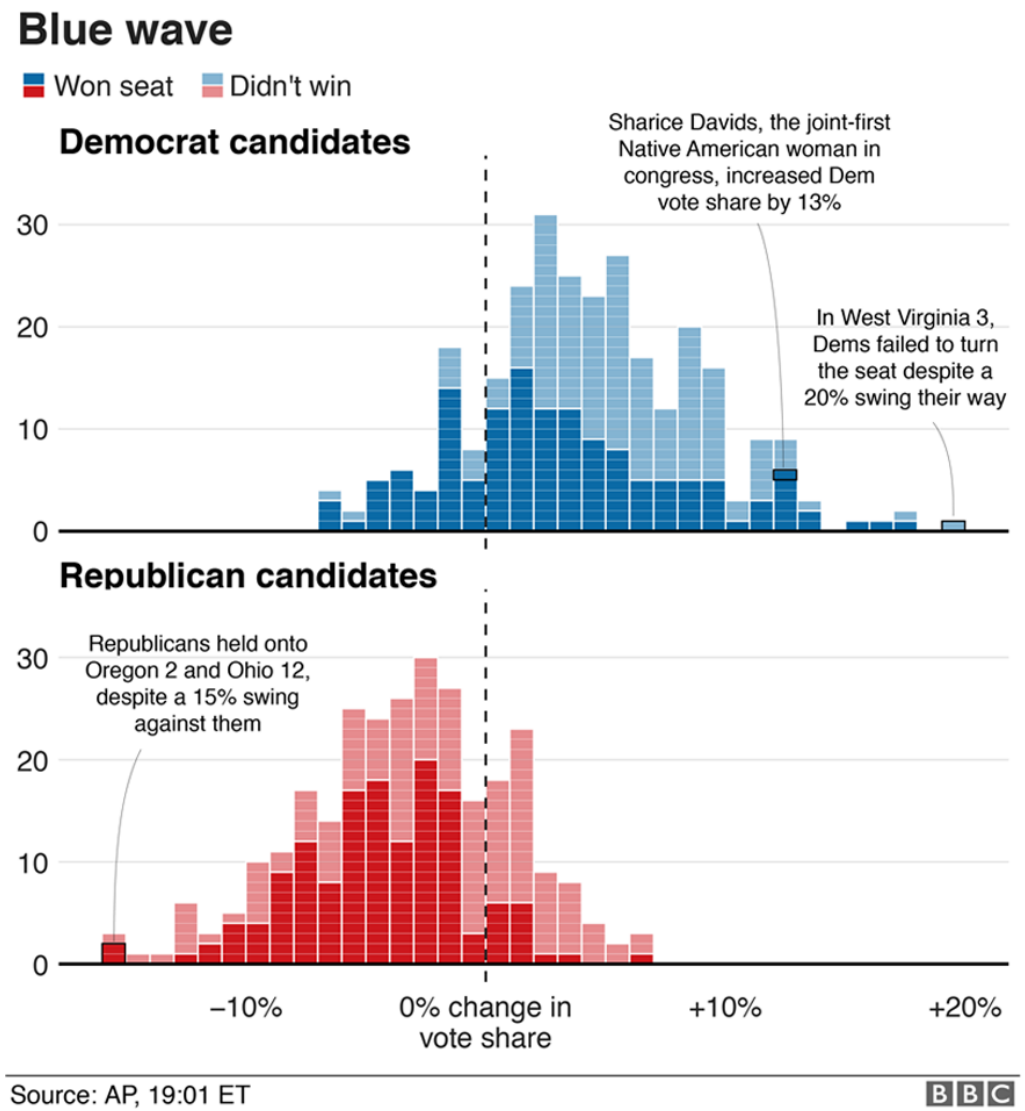
Questions to ask:

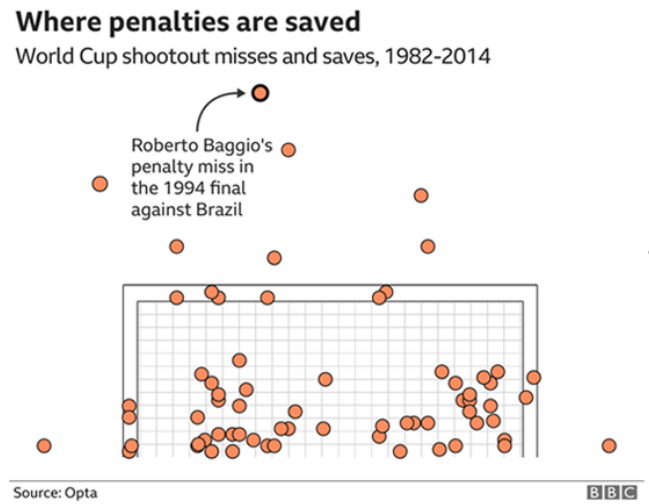
- Are you already using R? Why switch?
- Are you going to have to share this process or reproduce it? Try R!
- Is it a quick project, or will others work on it? Maybe Excel is fine.
- Do you need to try a bunch of charts quickly, build interactive components, etc? Tableau might be more powerful and faster.

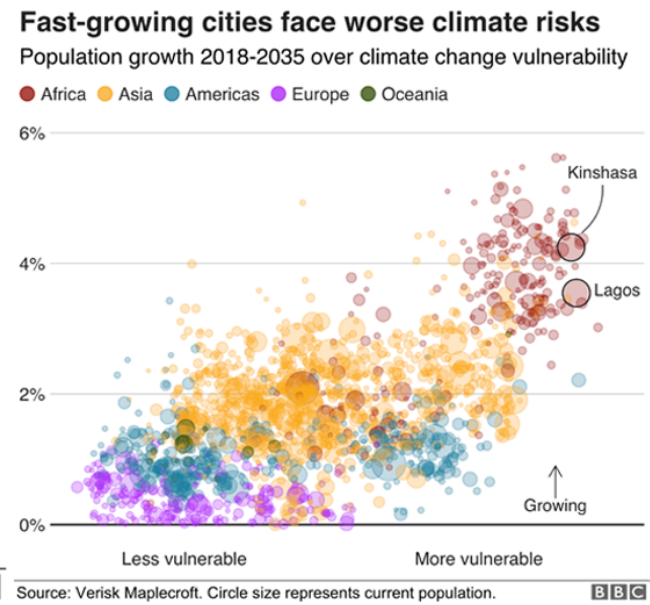
ggplot2 examples

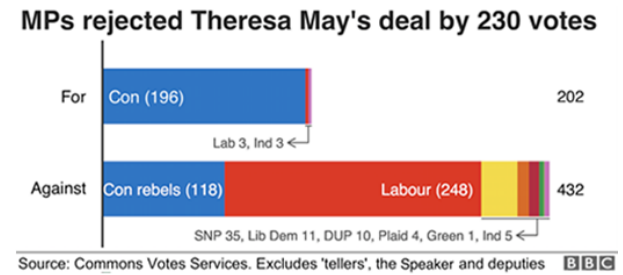


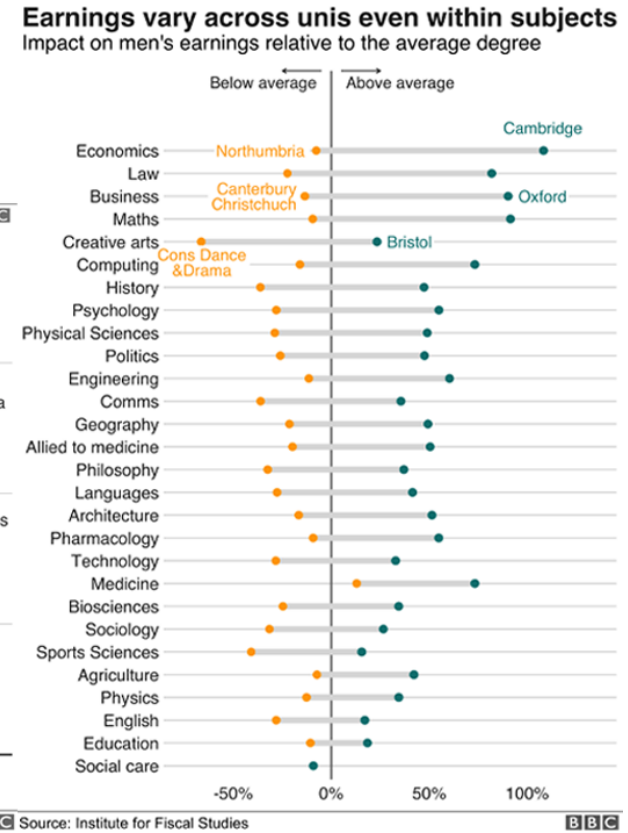
http://socviz.co/groupfacettx.html



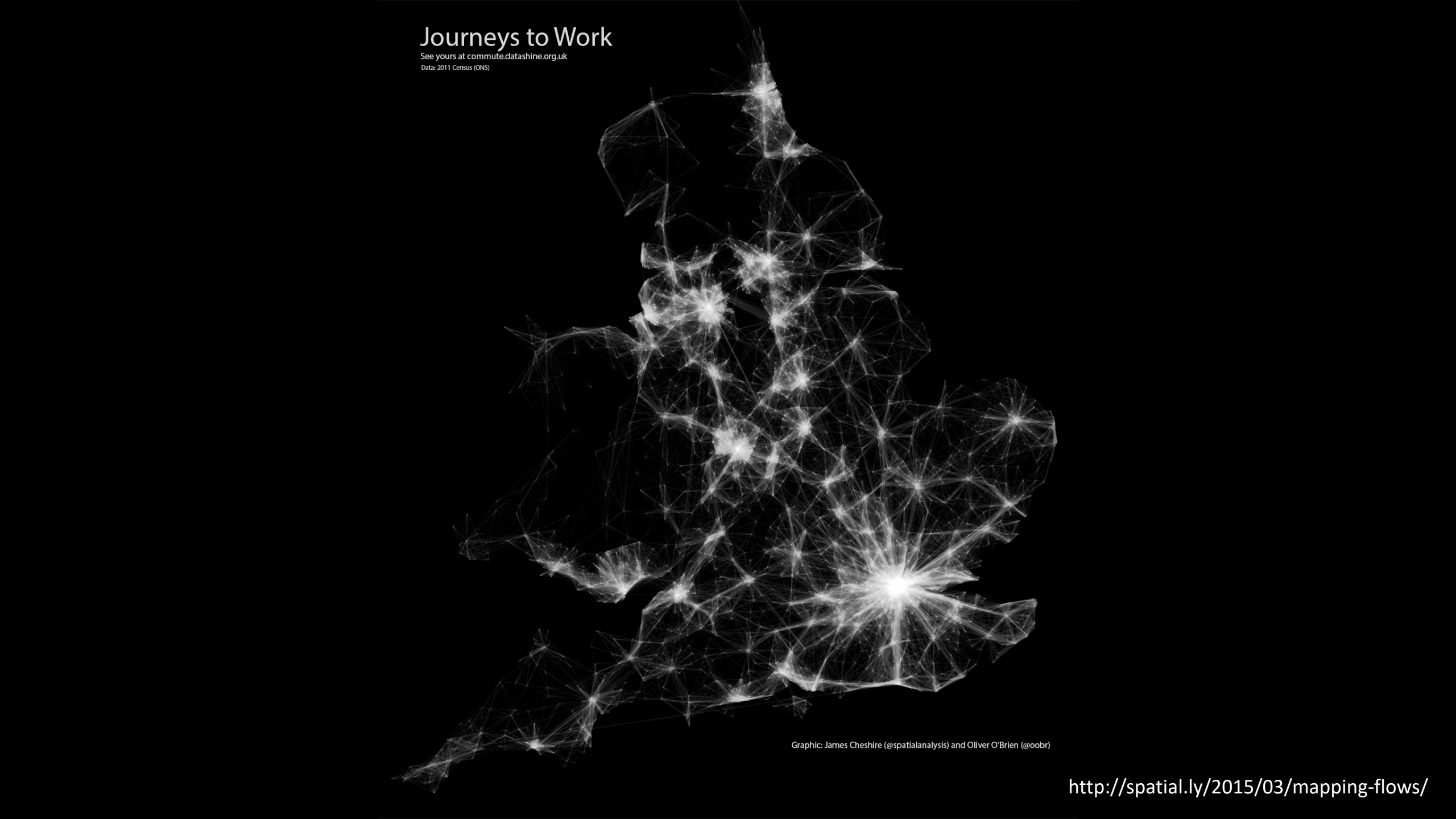




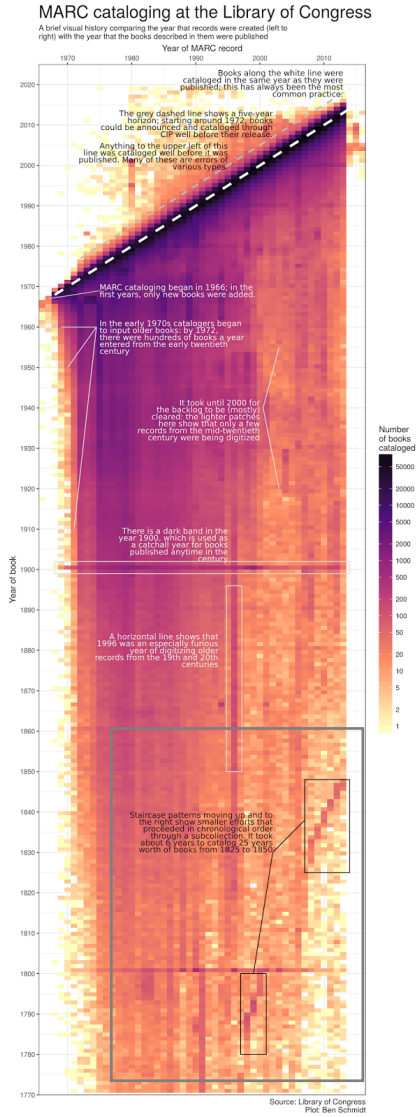


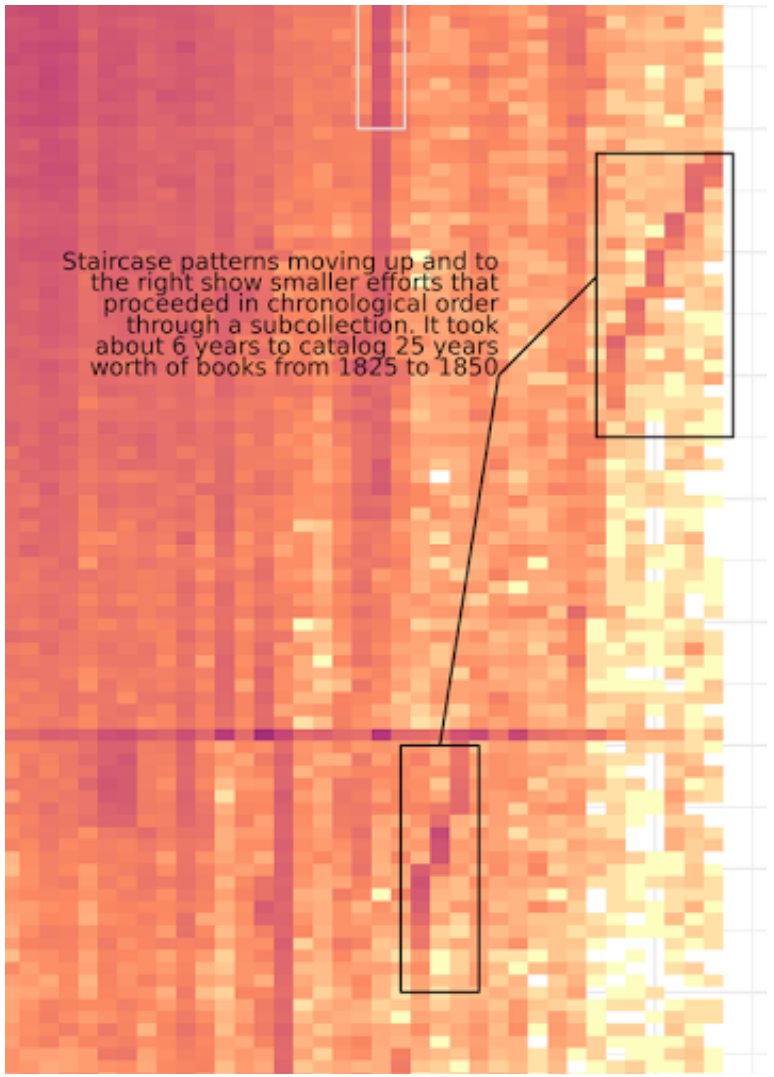


https://bbc.github.io/rcookbook/



http://spatial.ly/2015/03/mapping-flows/



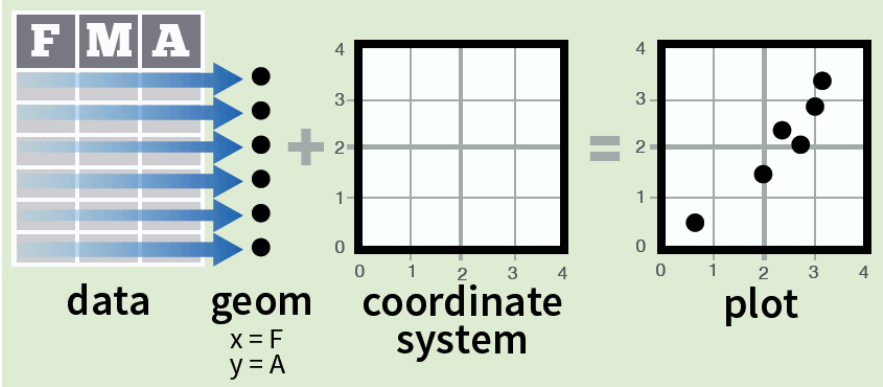


http://sappingattention.blogspot.com/2017/05/a-brief-visual-history-of-marc.html

ggplot2: Elements

Basic elements in any ggplot2 visualization

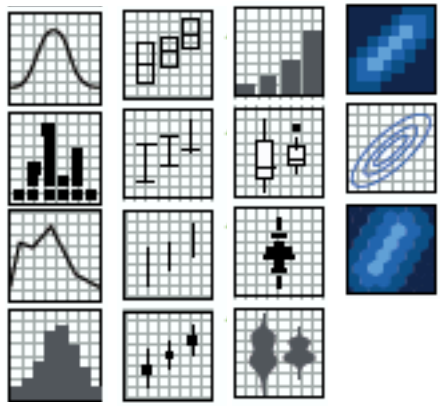
- **data**
- **aes**thetics
  (variable mappings)
- **geom**
  (chart type or shape)
- coordinate system
  (the arrangement of the marks;
  most geoms use default, cartesian)



http://bit.ly/ggplot2-cheatsheet

Types of geoms

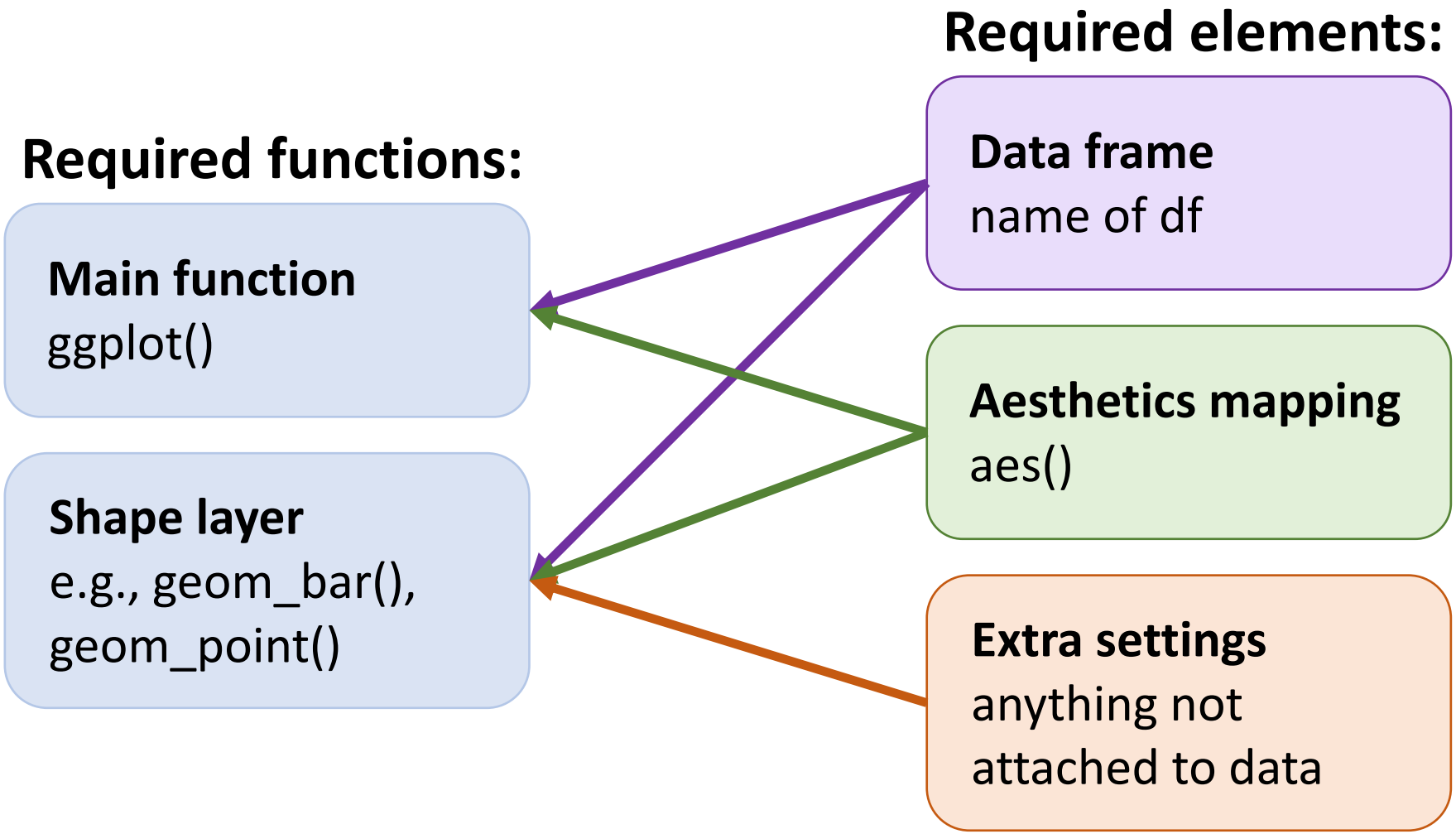
- geom_bar()
- geom_point()
- geom_histogram()
- geom_map()
- etc.



http://bit.ly/ggplot2-cheatsheet

Note: some geoms also include data summary functions.
e.g., the “bar” geom will count data points in each category.

ggplot2: Basic syntax


Required functions:
Main function
ggplot()
Shape layer
e.g., geom_bar(),
geom_point()
Required elements:
Data frame
name of df
Aesthetics mapping
aes()
Extra settings
anything not
attached to data

Template for a simple plot

Main function

```
ggplot( data = data frame )  +
```

Shape layer

```
geom_...( mapping = aes(variable mappings),
          non-variable adjustments )
```

Step-by-step

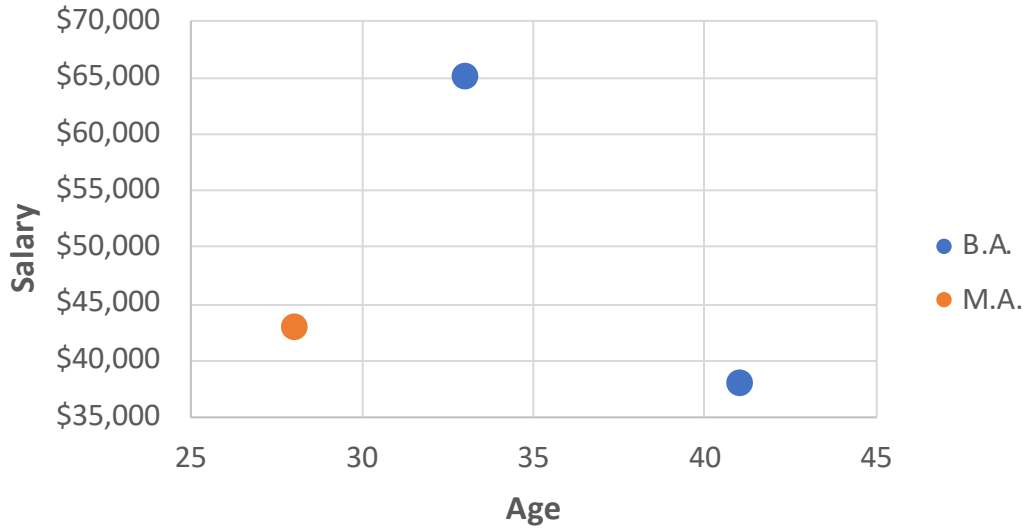
1. Set the data
2. Choose a shape layer
3. Map variables to aesthetics
4. Add non-variable adjustments

1. Set the data

“employees”

Name	Age	Salary	Highest Degree
Jane Smith	33	$65,000	B.A.
Abby Jones	28	$43,000	M.A.
Bridget Carden	41	$38,000	B.A.

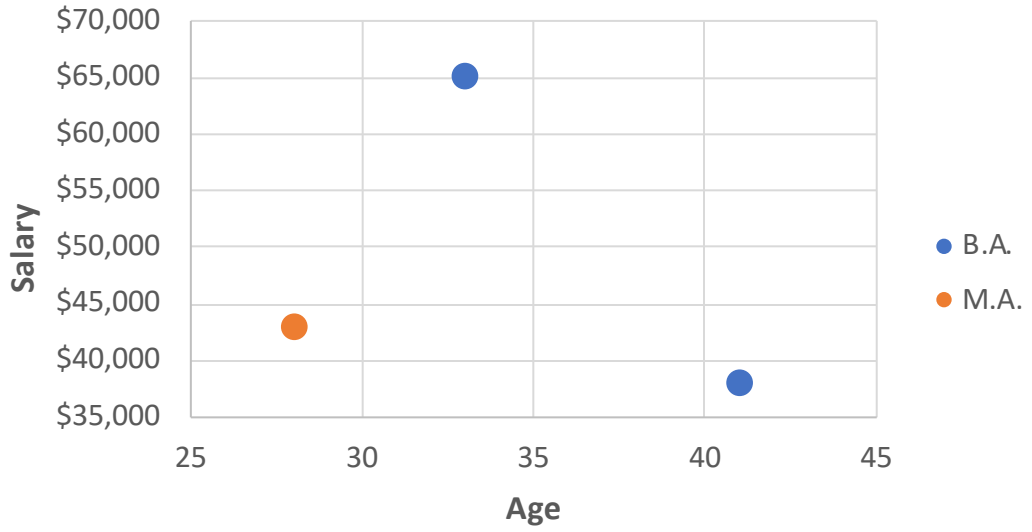
```
ggplot(employees)
```



2. Choose a shape layer

Name	Age	Salary	Highest Degree
Jane Smith	33	$65,000	B.A.
Abby Jones	28	$43,000	M.A.
Bridget Carden	41	$38,000	B.A.

```
ggplot(employees) +
    geom_point()
```

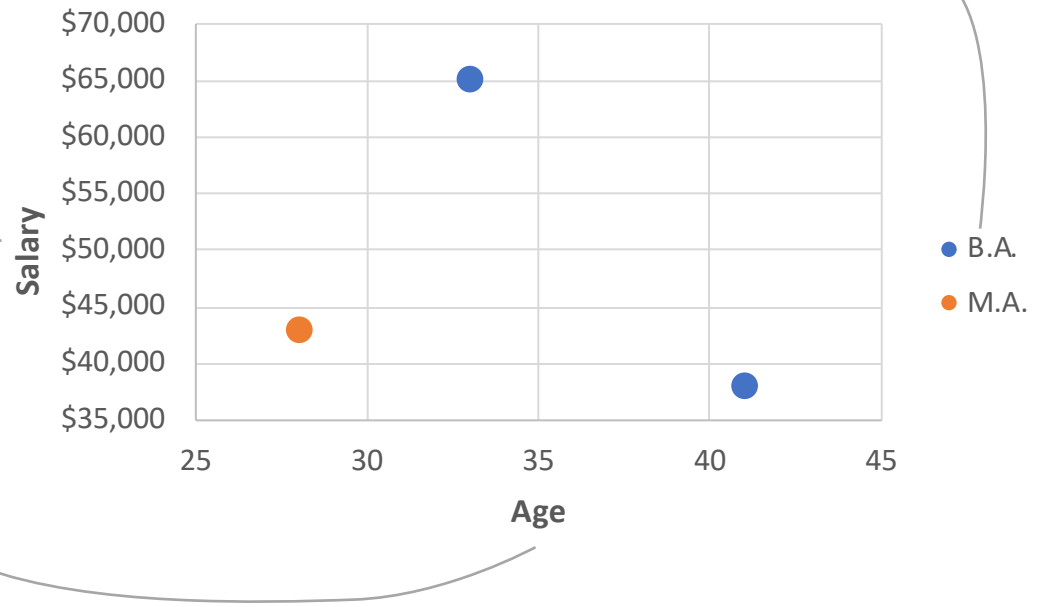


3. Map variables to aesthetics

Name	Age	Salary	Highest Degree
Jane Smith	33	$65,000	B.A.
Abby Jones	28	$43,000	M.A.
Bridget Carden	41	$38,000	B.A.

```
ggplot(employees) +
    geom_point(
        aes(x=age,
            y=salary,
            color=degree))
```

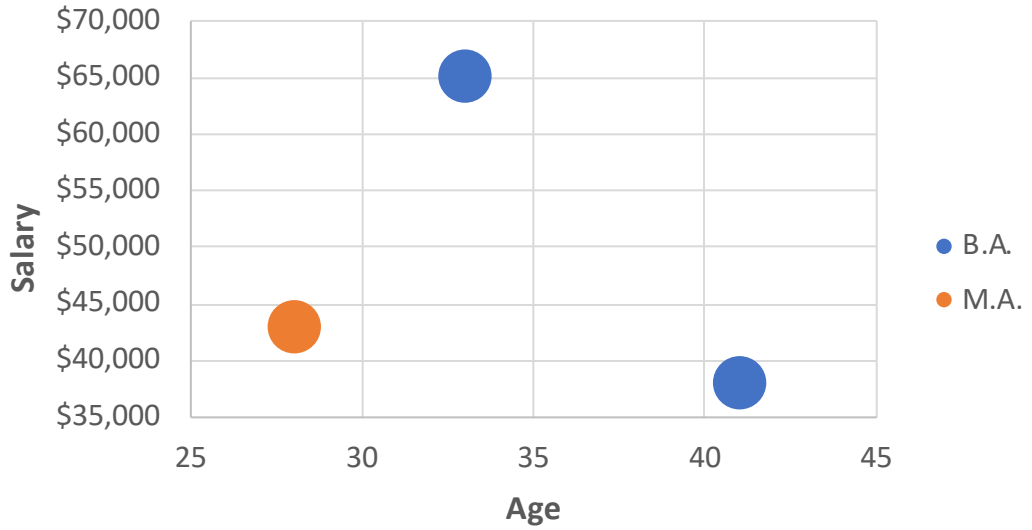
x position y position color



4. Add non-variable adjustments

Name	Age	Salary	Highest Degree
Jane Smith	33	$65,000	B.A.
Abby Jones	28	$43,000	M.A.
Bridget Carden	41	$38,000	B.A.

```
ggplot(employees) +
    geom_point(
        aes(x=age,
            y=salary,
            color=degree),
        size=10)
```



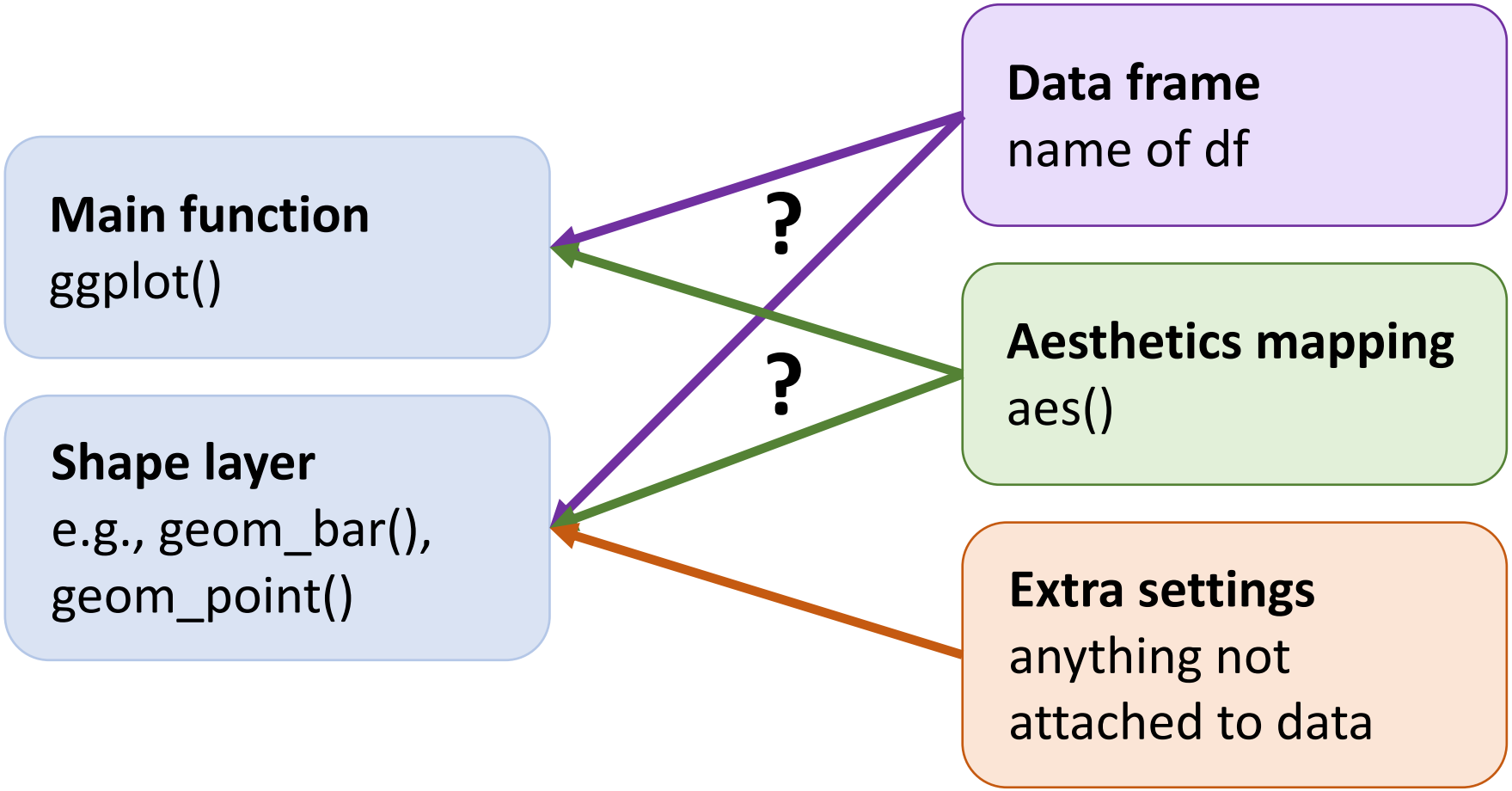
Template for a simple plot

Main function

```
ggplot( data = data frame )  +
```

Shape layer

```
geom_...( mapping = aes(variable mappings),
          non-variable adjustments )
```


Main function
ggplot()
Shape layer
e.g., geom_bar(),
geom_point()
?
?
Data frame
name of df
Aesthetics mapping
aes()
Extra settings
anything not
attached to data

Inheritance

data and aesthetics will carry through from main function to shape layers

Main function

```
ggplot( data = data frame,
        mapping = aes(variable mappings) )
```

+

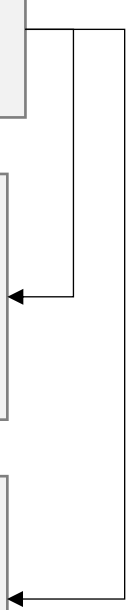
Shape layer

```
geom_...( aes(add'l variable mappings),
          non-variable adjustments )
```

+

Shape layer

```
geom_...( aes(add'l variable mappings),
          non-variable adjustments )
```



General inheritance strategy

Main function

```
ggplot( main data frame,
        aes(x, y) )
```

+

Shape layer

```
geom_...( aes(add'l variable mappings),
          non-variable adjustments )
```

+

Shape layer

```
geom_...( aes(add'l variable mappings),
          non-variable adjustments )
```

Additional decisions

Adding something that will appear
inside the **chart coordinate space**?

You will (almost always) be adding a **geom**!

Changing the way a **variable is displayed**?
(e.g., different axis breaks, different color mapping)

You will be adding a **scale**!

Changing the **look and feel** of the chart?

You will be adding or making changes to a **theme!**

Working in RStudio

Get workshop files

URL: https://github.com/amzoss/RVis-DM2019

With Git installed

In RStudio:

- Project → New project
- Version Control
- Git
  - Paste in GitHub URL
  - Project directory name: RVis-DM2019
  - Subdirectory: you choose
- Create Project

Without Git installed

- Click green button to download ZIP
- Unzip files on your laptop

In RStudio:

- Project → New project…
- Existing directory
- Select unzipped folder
- Create Project

Problems?

Try RStudio Cloud:

http://bit.ly/RVisCloud

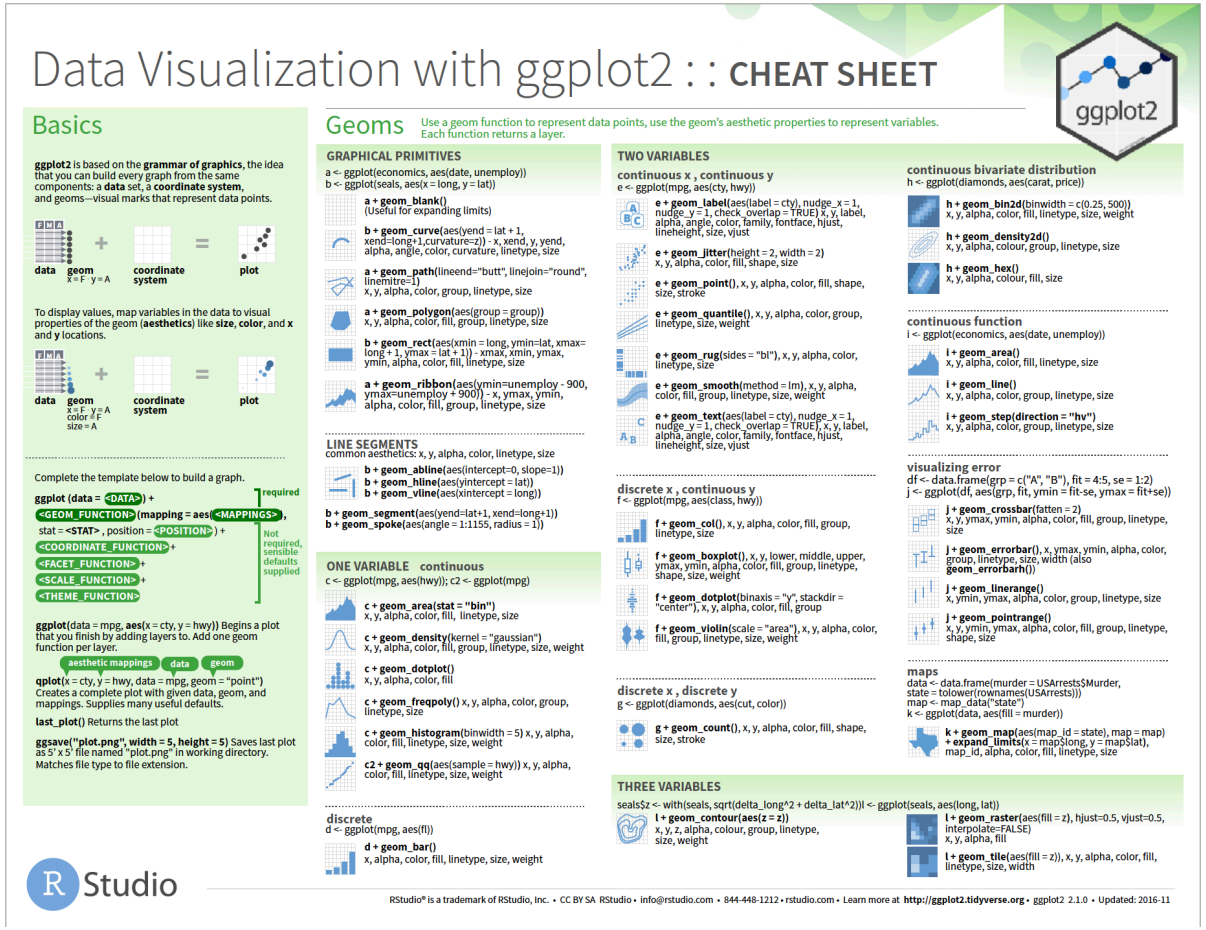
Using RStudio

- Projects
- Rmarkdown
- Cheat sheets

Try right now:
Open RStudio
Try running “library(tidyverse)”
Tell me about any errors

https://www.rstudio.com/resources/cheatsheets/#rmarkdown

ggplot2 Cheat Sheet



https://www.rstudio.com/resources/cheatsheets/#ggplot2

Notes about RMarkdown

- Comments work like HTML
  <!--HTML Comment style -->
- Practice a few non-code markdown elements (see cheat sheet)

Debugging code

- Start simple
- If you see an error:
  - read error message for hints
  - check for problems with spelling/punctuation marks
- Get code to run without errors
- Check result to see if it makes sense

- Add a small change
- Get code to run without errors
- Check result to see if it makes sense
- etc.

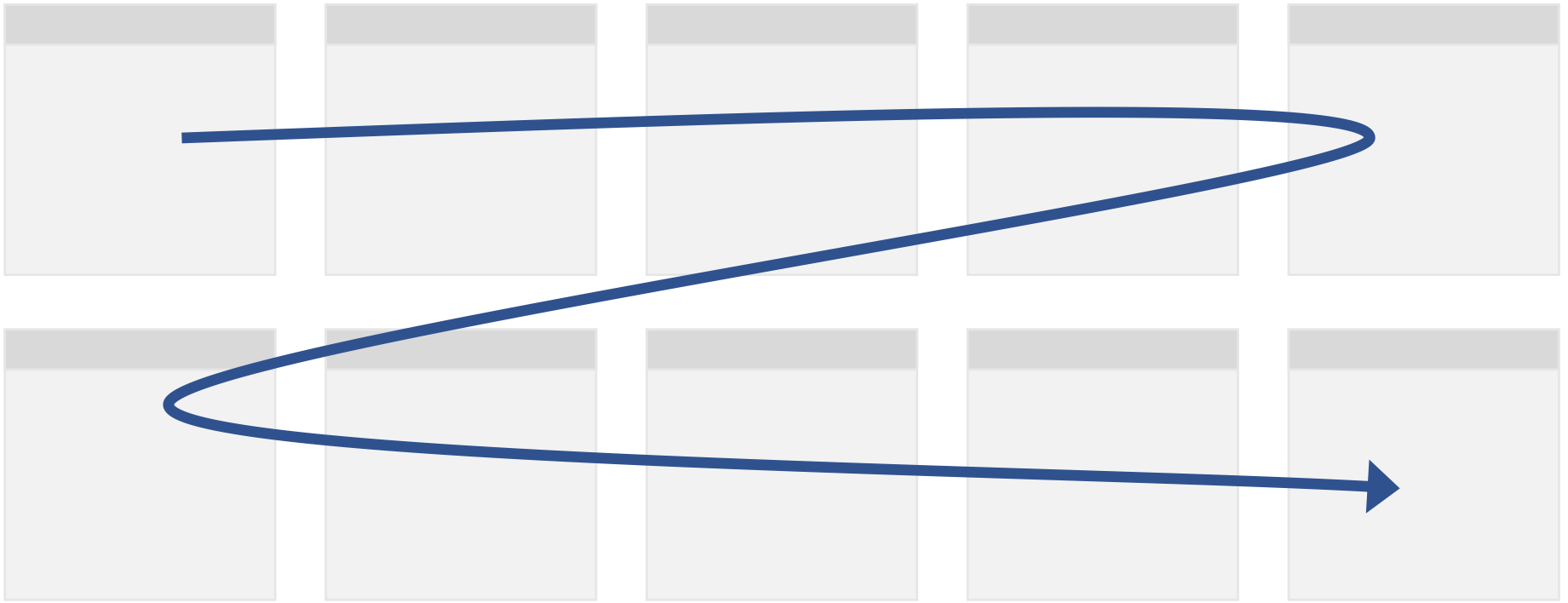
Dataset 1:
Game of Thrones character ratings

https://www.nytimes.com/interactive/2017/08/09/upshot/game-of-thrones-chart.html

Creating repeated charts

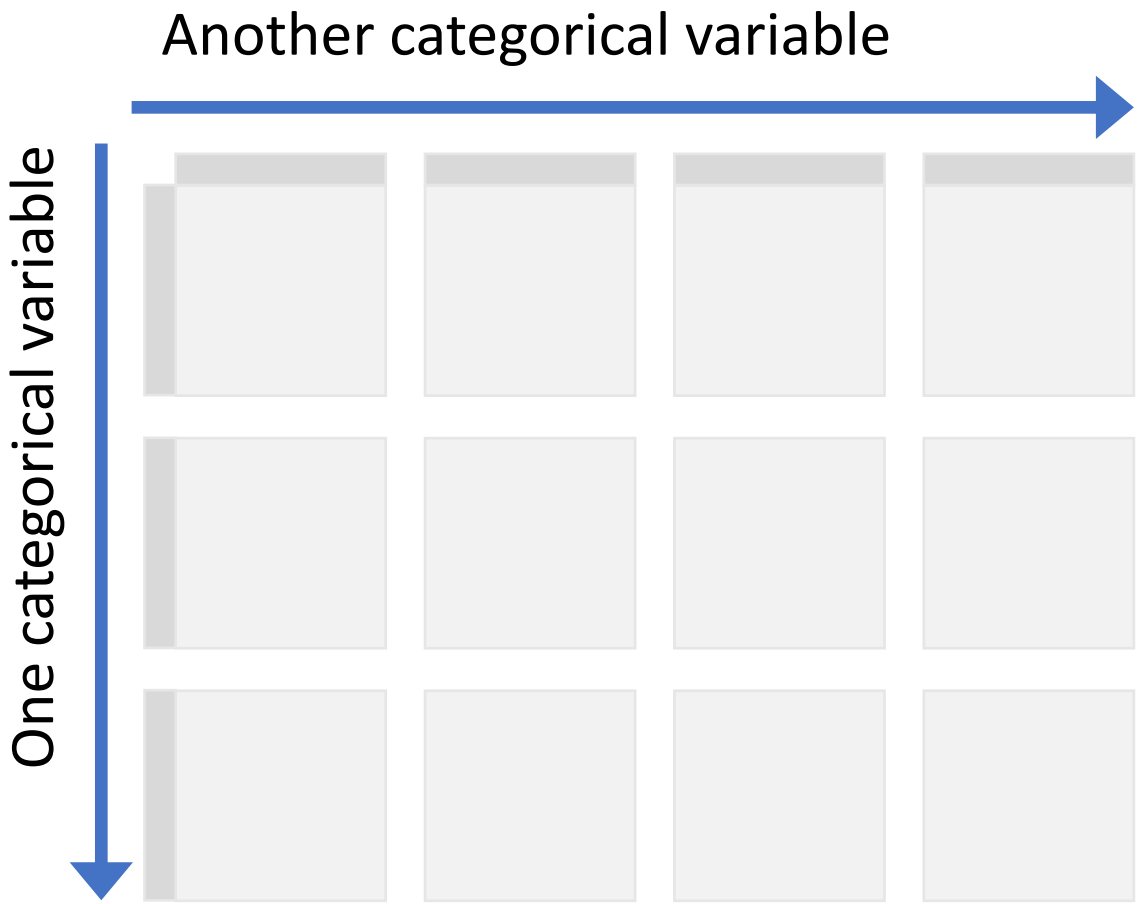
facet_wrap()

```
+ facet_wrap(vars(variable))
```



facet_grid()

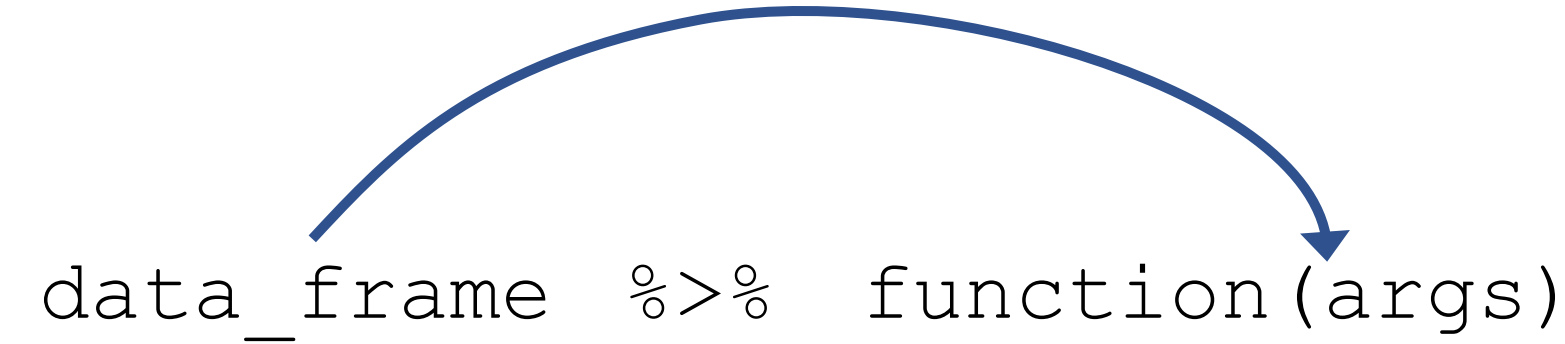
```
+ facet_grid(rows=vars(yvar,
                       cols=vars(xvar))
```



Helpful data manipulation

About %>%

- Loads automatically with tidyverse
- Used throughout tidyverse (except for ggplot2)
- Pushes data from the left into the function on the right



filter

Select a subset of rows

```
data %>% dplyr::filter(name == "John")
```

same as

```
dplyr::filter(data, name == "John")
```

https://www.rstudio.com/resources/cheatsheets/#dplyr

select

Select a subset of columns (many options!)

```
data %>% dplyr::select(id, name, age)
```

```
data %>% dplyr::select(-count)
```

https://www.rstudio.com/resources/cheatsheets/#dplyr

drop_na

Remove rows with NA values, either in any column or in specified columns

```
data %>% drop_na()
```

```
data %>% drop_na(age)
```

https://www.rstudio.com/resources/cheatsheets/#import

Dataset 2:
Star Wars character data

https://dplyr.tidyverse.org/reference/starwars.html

Working with text variables

Text variables

In R, "character" variables

Gender	Age	Household Income	Education
Response	Response	Response	Response
Male	18-29		High school degree
Male	18-29	$0 - $24,999	Bachelor degree
Male	18-29	$0 - $24,999	High school degree
Male	18-29	$100,000 - $149,999	Some college or Associate degree
Male	18-29	$100,000 - $149,999	Some college or Associate degree
Male	18-29	$25,000 - $49,999	Bachelor degree
Male	18-29		High school degree
Male	18-29		High school degree
Male	18-29	$0 - $24,999	Some college or Associate degree
Male	18-29	$25,000 - $49,999	Some college or Associate degree
Male	18-29	$25,000 - $49,999	Bachelor degree
Male	30-44	$50,000 - $99,999	Graduate degree
Male	18-29		High school degree
Male	18-29	$0 - $24,999	Some college or Associate degree
Male	18-29	$50,000 - $99,999	Bachelor degree

Factors

- Default ordering for categories: alphabetical
- Converting to factor allows you to:
  - Specify “levels” for a categorical variable
  - Specify the order of those levels
  - Specify whether the factor is “ordered”

https://r4ds.had.co.nz/factors.html

```
> x1 <- c("Dec", "Apr", "Jan",
"Mar")

> factor(x1)
[1] Dec Apr Jan Mar
Levels: Apr Dec Jan Mar

> month_levels <- c( "Jan", "Feb",
"Mar", "Apr", "May", "Jun", "Jul",
"Aug", "Sep", "Oct", "Nov", "Dec" )

> y1 <- factor(x1,
               levels = month_levels)
> y1
[1] Dec Apr Jan Mar
Levels: Jan Feb Mar Apr May Jun Jul
Aug Sep Oct Nov Dec
```

forcats package: helpful functions

- `as_factor(char_var)`:
  convert a character variable to a factor
- `fct_infreq(factor)`:
  take factor levels and set the order according to (inverse) category frequency
- `fct_reorder(factor, num_var)`:
  sort factor levels by a second, numerical variable (like a pre-calculated count or average)

https://www.rstudio.com/resources/cheatsheets/#forcats

Note about read.csv (base R)

- Converts string variables to factors by default
- Can either:
  - Include `stringsAsFactors=FALSE`
  - Use `read_csv()` instead

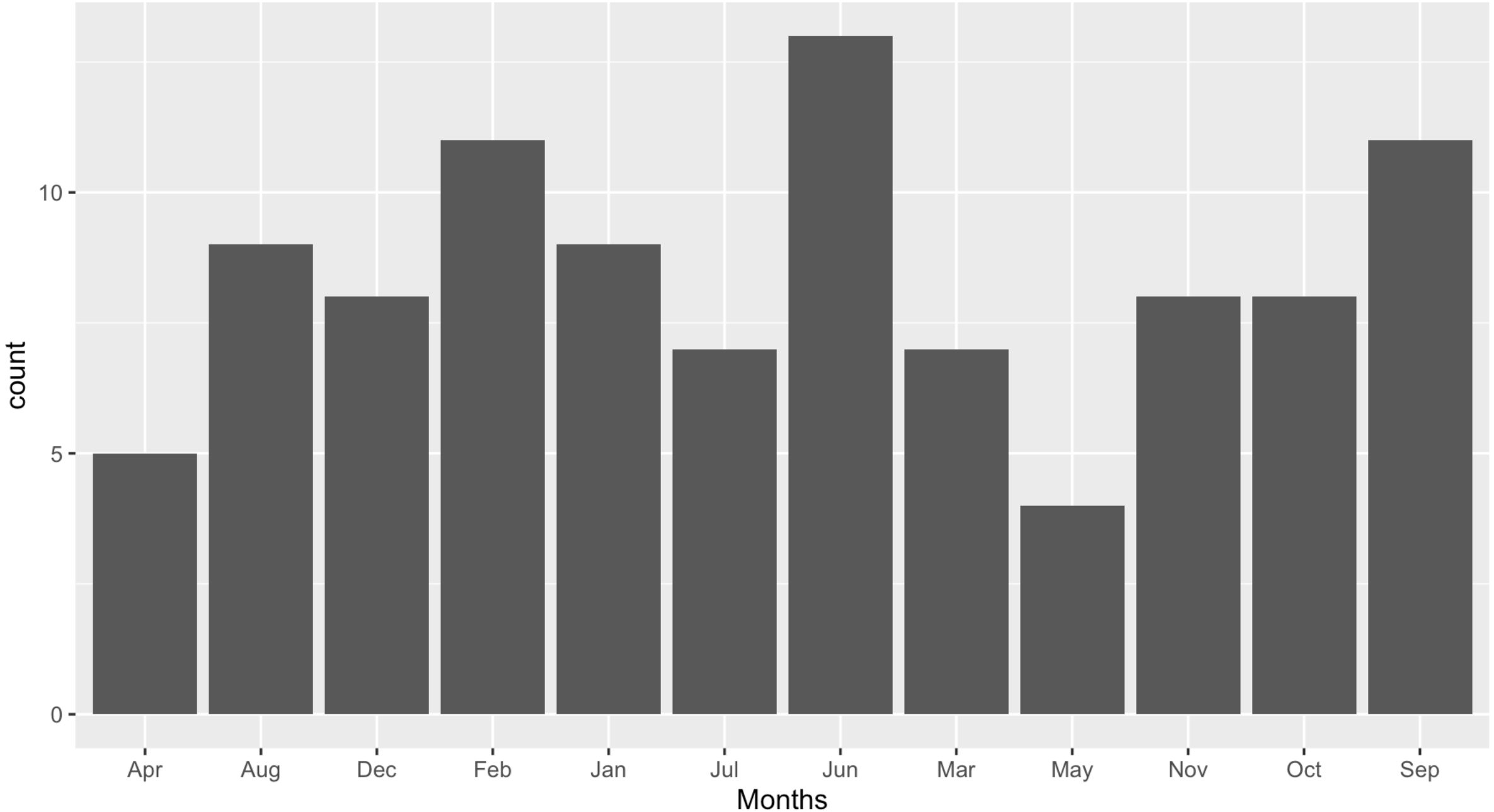
Factoring resources

From Amelia McNamara:

- RStudioConf 2019 slides:
  Working with Categorical Data in R Without Losing Your Mind
- Wrangling Categorical Data in R article
- Wrangling Categorical Data in R repository

Design Principles for Text Variables

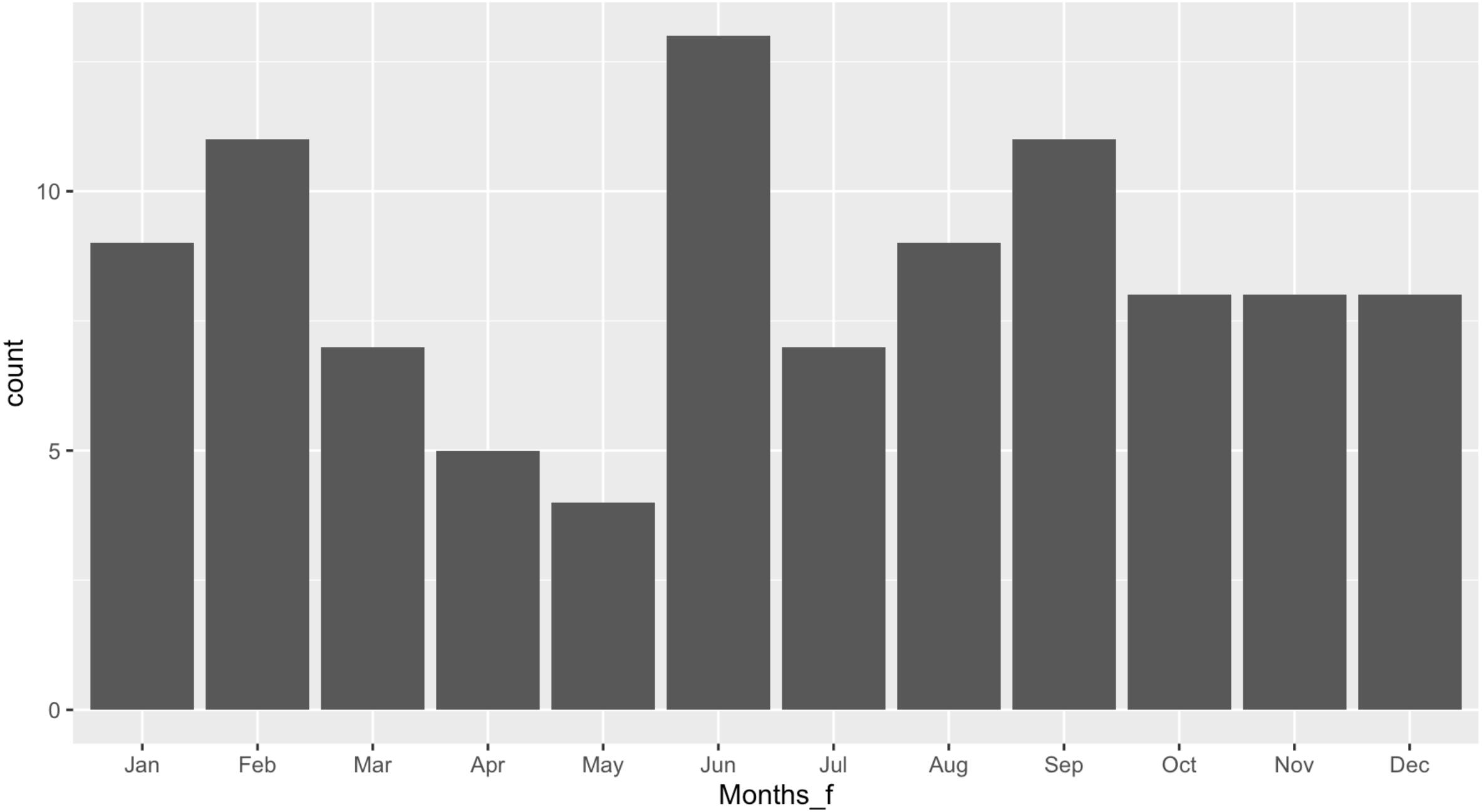
Principle 1: Order matters

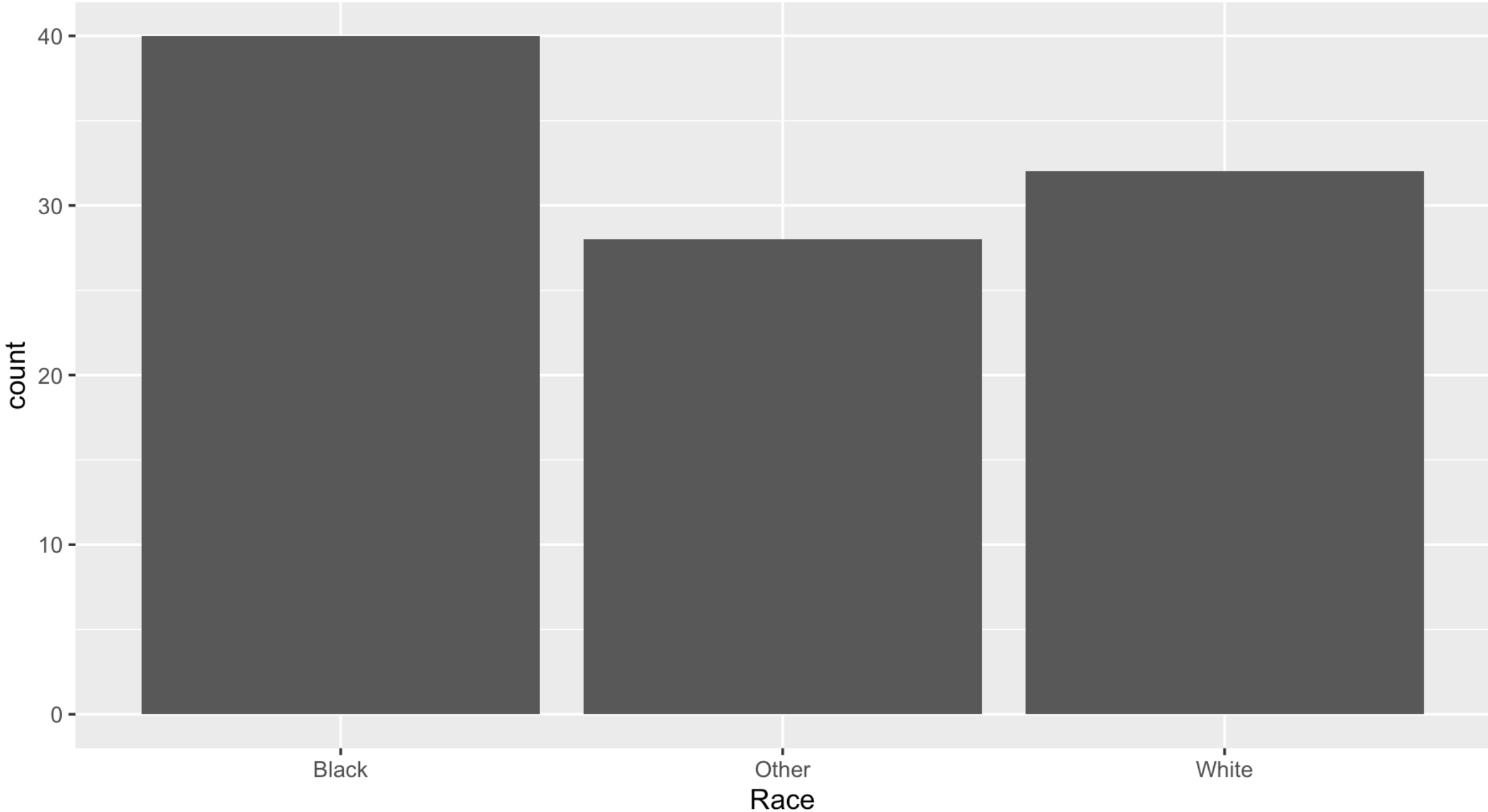

count
10
5
0
Apr
Aug
Dec
Feb
Jan
Jul
Jun
Mar
May
Nov
Oct
Sep
Months

Order by meaning

```
month_levels <- c( "Jan", "Feb", "Mar", "Apr",
"May", "Jun", "Jul", "Aug", "Sep", "Oct", "Nov",
"Dec" )


data <- data %>%
    mutate(Months_f = Months %>%
                      as_factor() %>%
                      fct_relevel(month_levels))
```

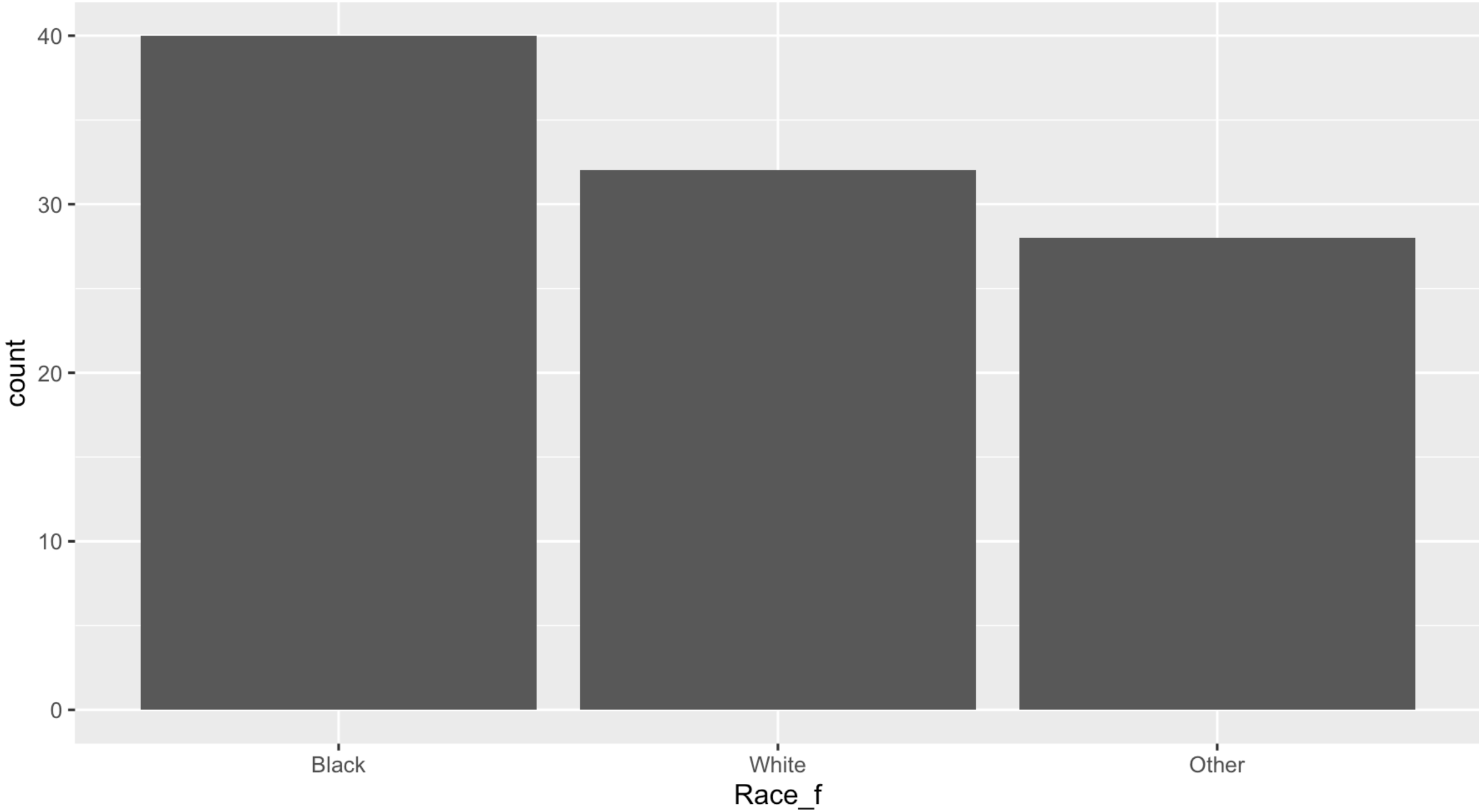

count
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months_f


40
30
20
10
0
count
Black
Other
White
Race

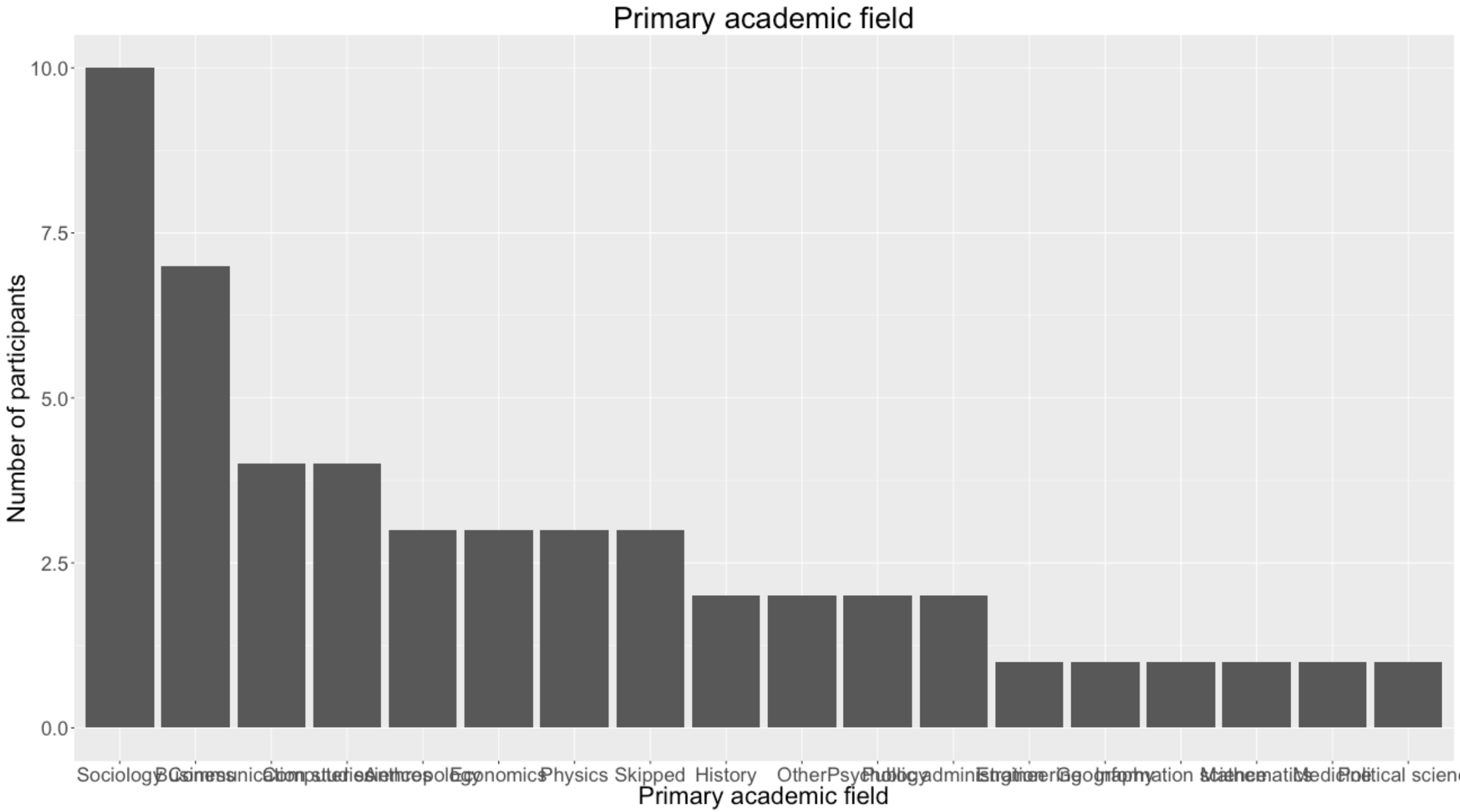
Order by value (using forcats)

```
demo <- data %>%
     mutate(Race_f = Race %>%
                        as_factor() %>%
                        fct_infreq())


ggplot(data,
         aes(Race %>%
                  as_factor() %>%
                  fct_infreq())) +
     geom_bar()
```

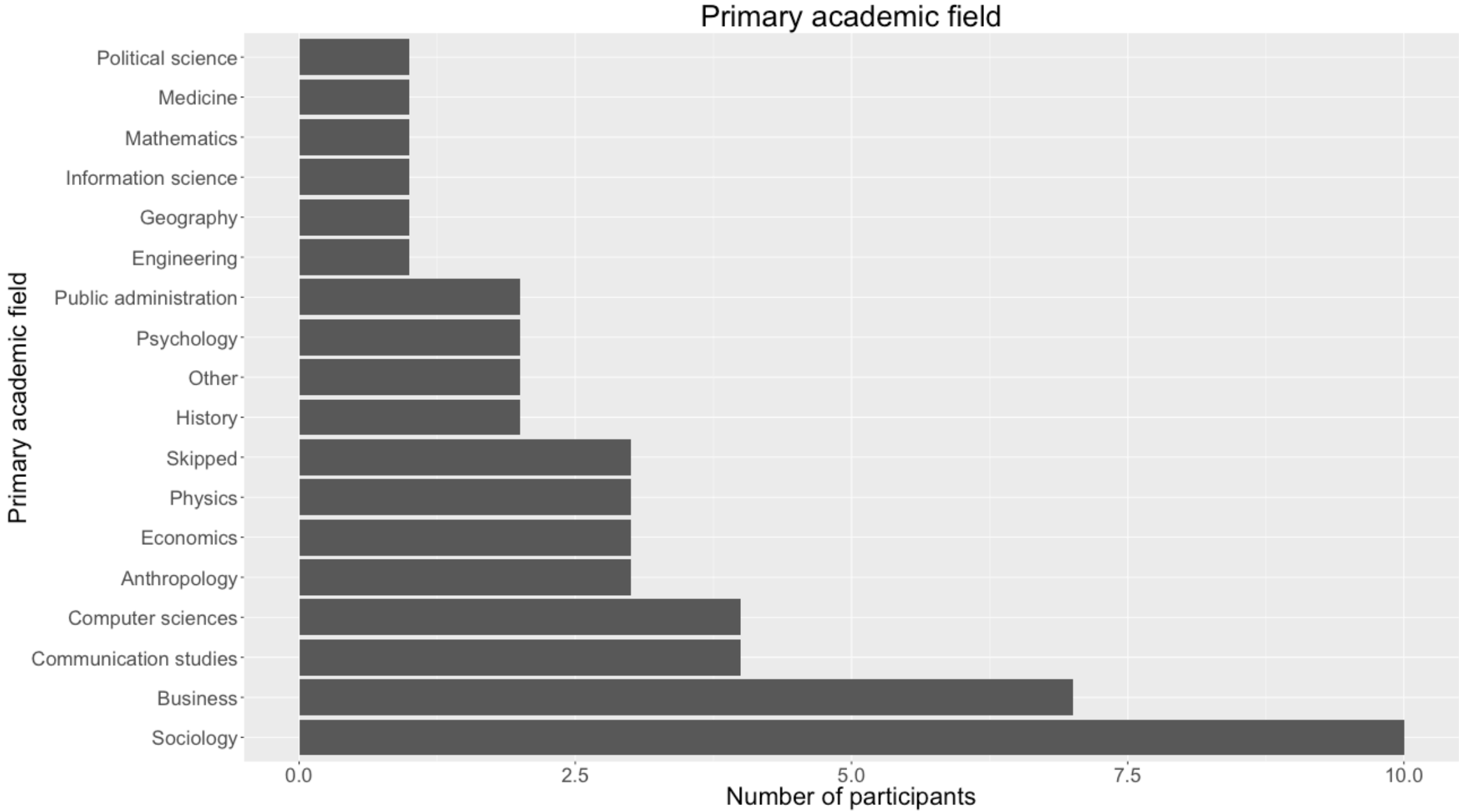

40
30
20
10
0
count
Black
White
Other
Race_f

Principle 2:
Put long categories on y-axis


Primary academic field
Number of participants
10.0
7.5
5.0
2.5
0.0
Sociology
Business
Computer science
Anthropology
Economics
Physics
Skipped
History
Other
Psychology
Public administration
Engineering
Geography
Information science
Mathematics
Medicine
Political scien
Primary academic field

Flip the axes

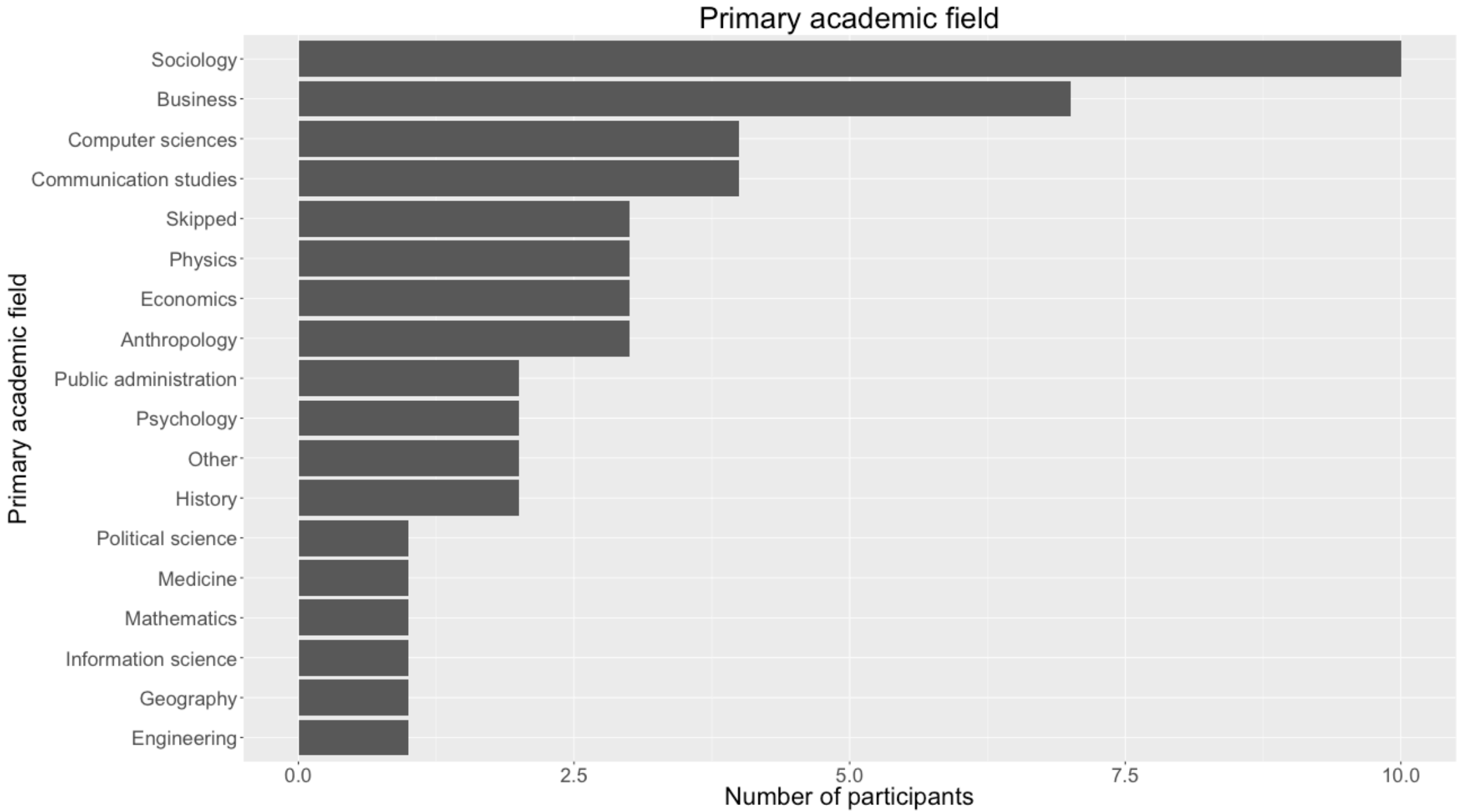
```
+ coord_flip()
```


Primary academic field
Political science
Medicine
Mathematics
Information science
Geography
Engineering
Public administration
Psychology
Other
History
Skipped
Physics
Economics
Anthropology
Computer sciences
Communication studies
Business
Sociology
Primary academic field
0.0
2.5
5.0
7.5
10.0
Number of participants

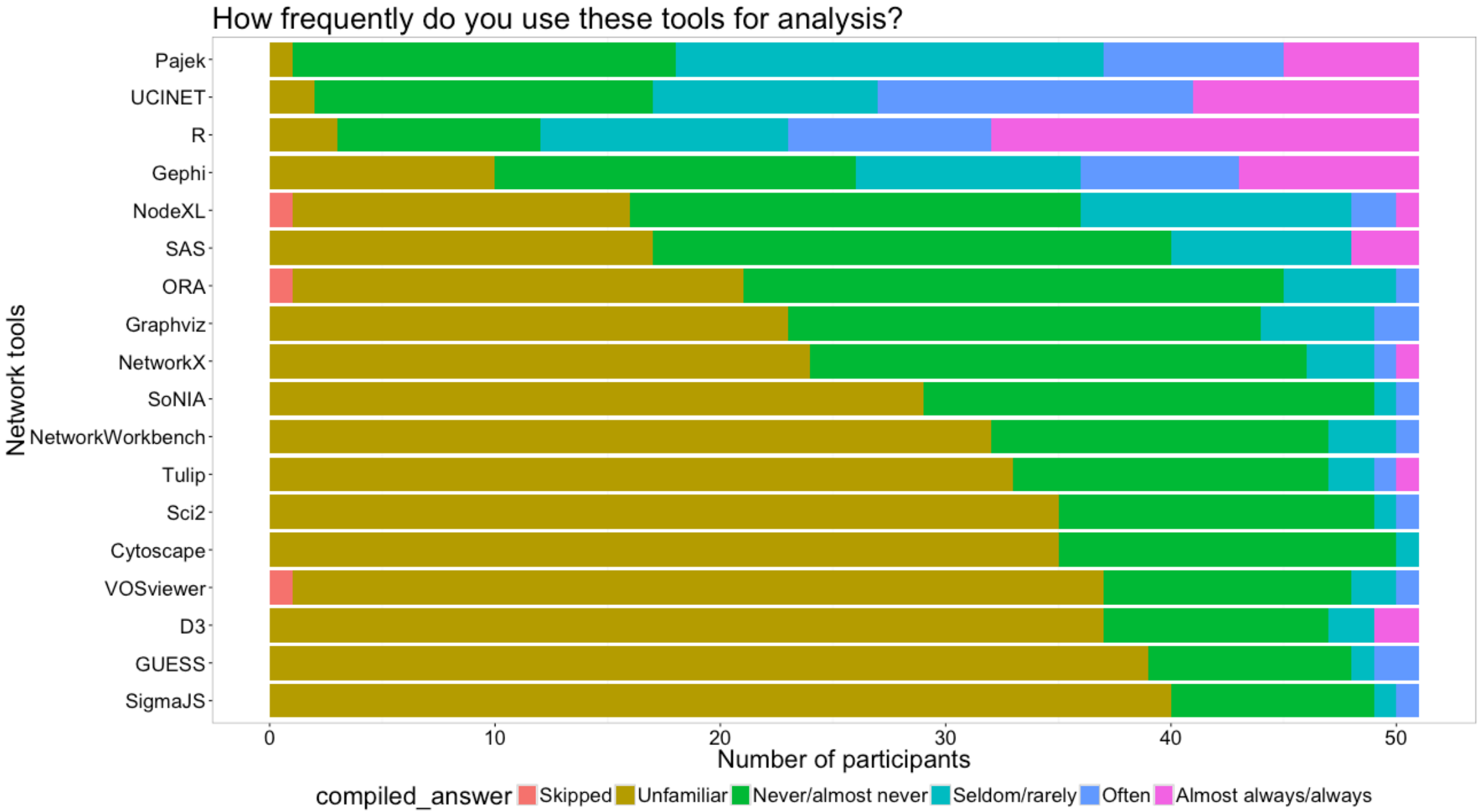
Oops!

```
data$academic_field <-
      fct_rev(fct_infreq(
        as_factor(data$academic_field)))
```

Have to reverse the order of the levels


Primary academic field
Sociology
Business
Computer sciences
Communication studies
Skipped
Physics
Economics
Anthropology
Public administration
Psychology
Other
History
Political science
Medicine
Mathematics
Information science
Geography
Engineering
Primary academic field
0.0
2.5
5.0
7.5
10.0
Number of participants

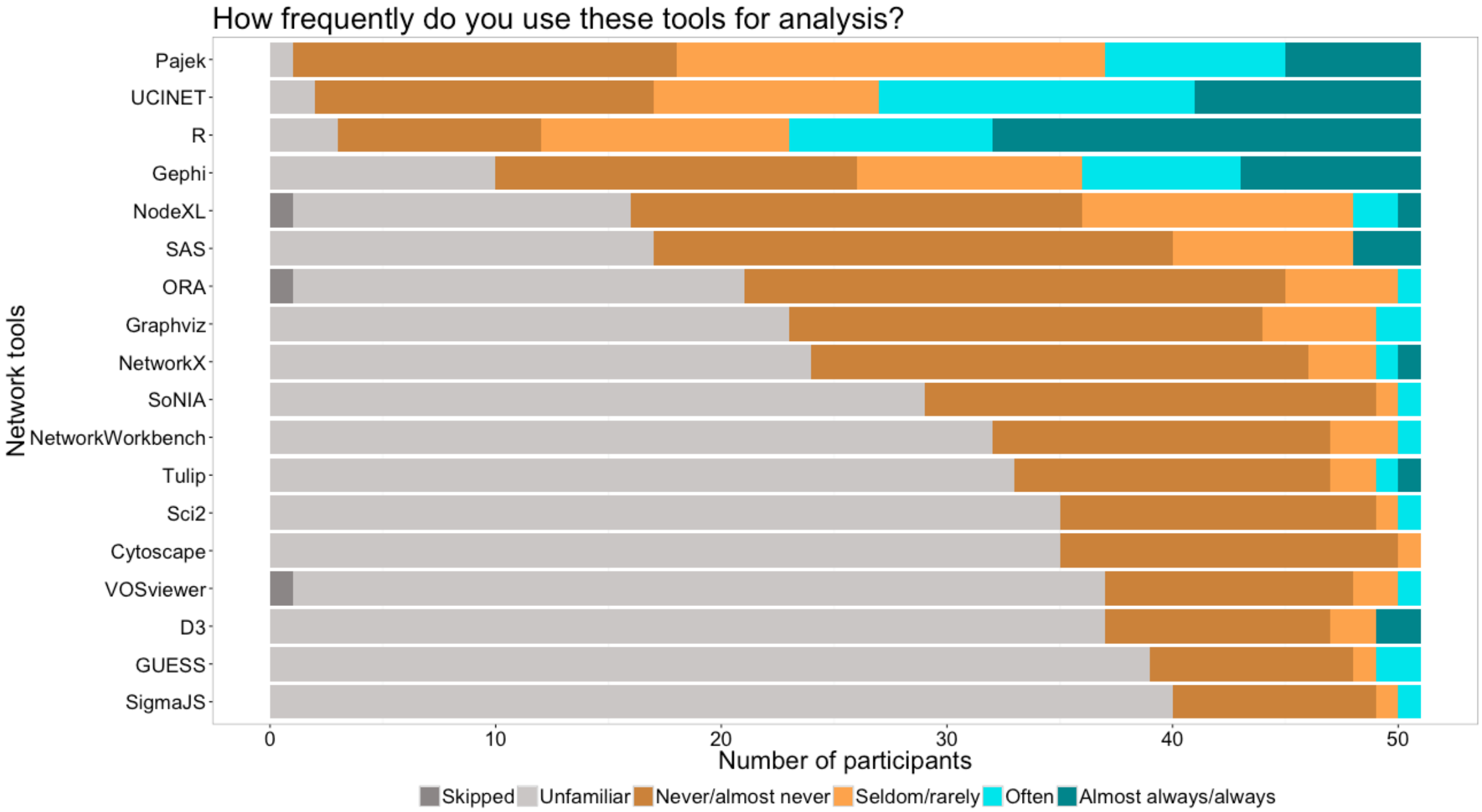
Principle 3:
Select meaningful colors


How frequently do you use these tools for analysis?
Network tools
Pajek
UCINET
R
Gephi
NodeXL
SAS
ORA
Graphviz
NetworkX
SoNIA
NetworkWorkbench
Tulip
Sci2
Cytoscape
VOSviewer
D3
GUESS
SigmaJS
0
10
20
30
40
50
Number of participants
compiled_answer
Skipped
Unfamiliar
Never/almost never
Seldom/rarely
Often
Almost always/always

Select colors manually, or use alternate palette

```
scale_fill_manual(
    values=c("snow4","snow3",
             "tan3","tan1",
             "turquoise2","turquoise4"))


# Also see package RColorBrewer
scale_fill_brewer(palette="BrBG")
```


How frequently do you use these tools for analysis?
Network tools
Pajek
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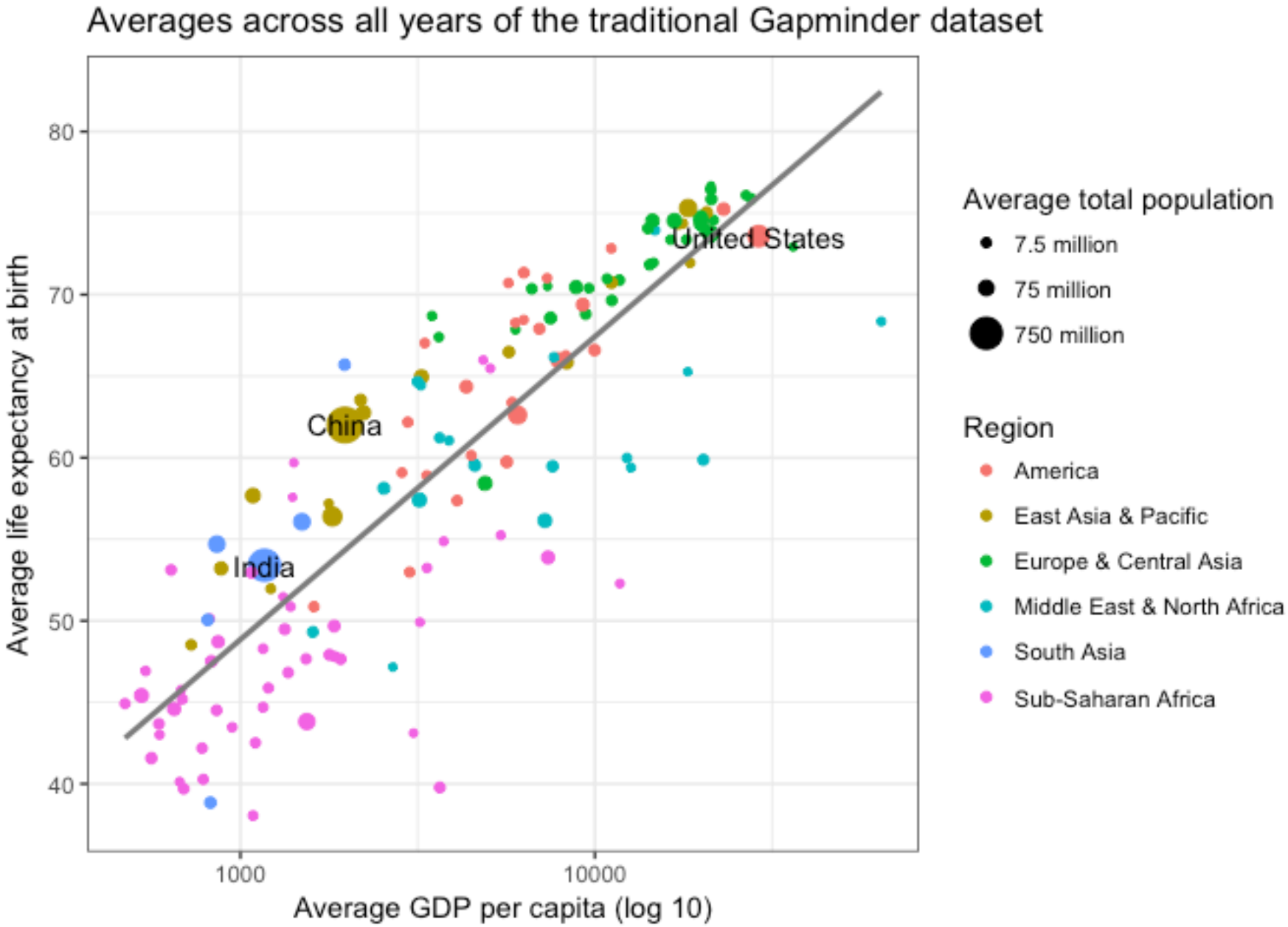
ORA
Graphviz
NetworkX
SoNIA
NetworkWorkbench
Tulip
Sci2
Cytoscape
VOSviewer
D3
GUESS
SigmaJS
0
10
20
30
40
50
Number of participants
Skipped
Unfamiliar
Never/almost never
Seldom/rarely
Often
Almost always/always

Dataset 3:
Star Wars opinion survey

https://fivethirtyeight.com/features/americas-favorite-star-wars-movies-and-least-favorite-characters/

Dataset 4: Gapminder Data

http://www.gapminder.org/


Averages across all years of the traditional Gapminder dataset
Average life expectancy at birth
80
70
60
50
40
1000
10000
Average GDP per capita (log 10)
China
India
United States
Average total population
7.5 million
75 million
750 million
Region
America
East Asia & Pacific
Europe & Central Asia
Middle East & North Africa
South Asia
Sub-Saharan Africa

Advanced topics:
Mapping, saving charts out

Mapping resources

- tigris for downloading TIGER/Line shapefiles
- sf (simple features) for spatial tables
  - Spatial Data Science book
  - Spatial Data Science in the tidyverse slides
  - Spatial Data Science in the tidyverse video

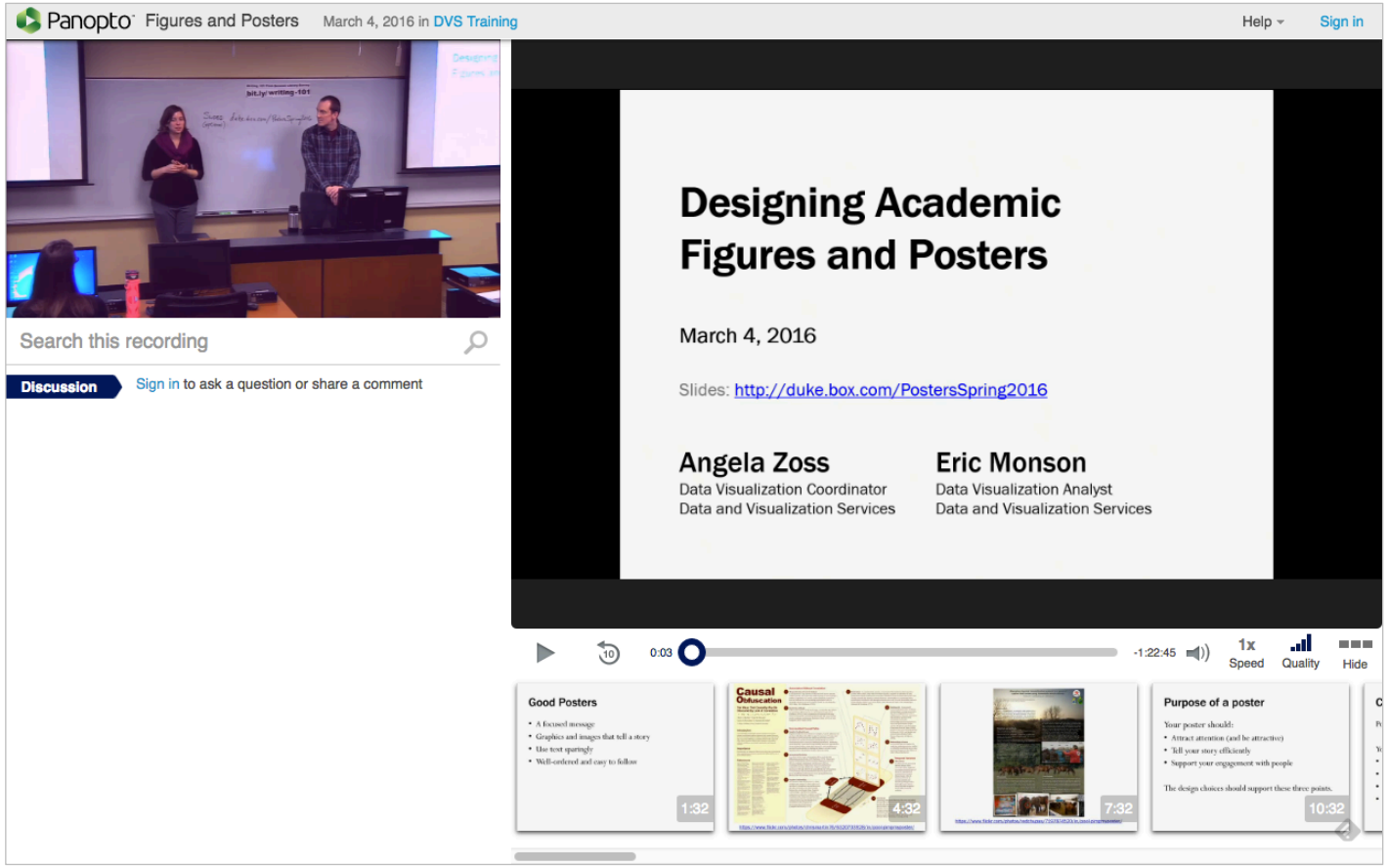
Other helper packages

- gganonymize to randomize text in ggplot2 figures
- visdat to visualize variable classes and missing data
- ggthemes for additional themes and scales, especially ones that match software defaults (e.g., Tableau)
- esquisse for building ggplot2 charts interactively
- colorblindr for simulating color vision deficiency
- ggpubr for publication-ready plots

ggplot2 Resources

- General ggplot2 information
  http://ggplot2.tidyverse.org/
- R Graphics Cookbook (recipes for plots)
  http://www.cookbook-r.com/Graphs/index.html
- R for Data Science (online book that includes ggplot2)
  http://r4ds.had.co.nz/
- ggplot2: Elegant Graphs for Data Analysis (book by Hadley Wickham)
  http://ggplot2.org/book/
- ggplot2 cheatsheet (also in RStudio)
  http://bit.ly/ggplot2-cheatsheet
- Data Carpentry lesson on ggplot2
- Data Visualization: A Practical Introduction, by Kieran Healy
- RStudio “Visualize Data” Primer

Videos of past workshops



http://bit.ly/DVSvideos

Thanks for your feedback!

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ggplot2: Chart quirks

See “templates” file

Chart components/slots

Bar chart, for example:

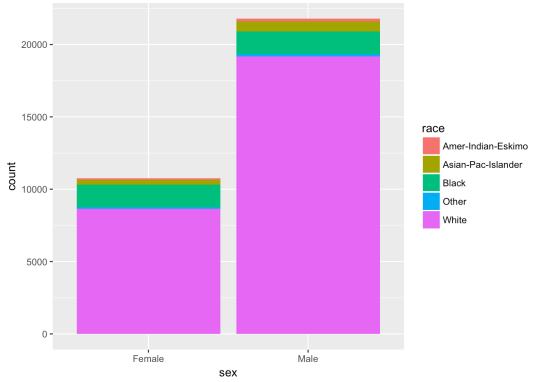
- x
  category (the names of the bars)

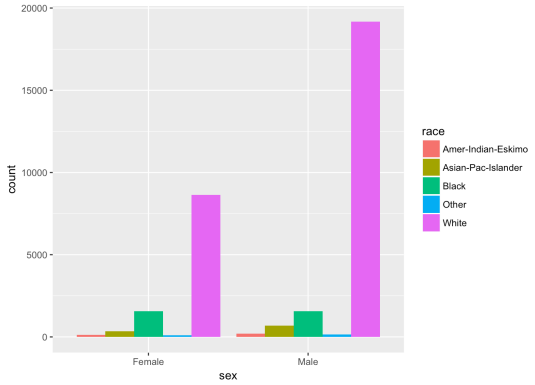
- y (optional)
  default is count, but can also specify a number (the length of the bars)

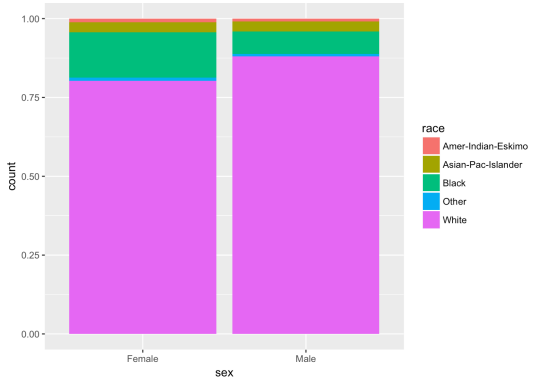
- color (optional)
  category (grouped or stacked bars)

Bar chart

- geom_bar() vs. geom_col()
- count vs. identity vs. summary
- categorical vs. continuous
- stack vs. dodge vs. fill
- bar vs. pie

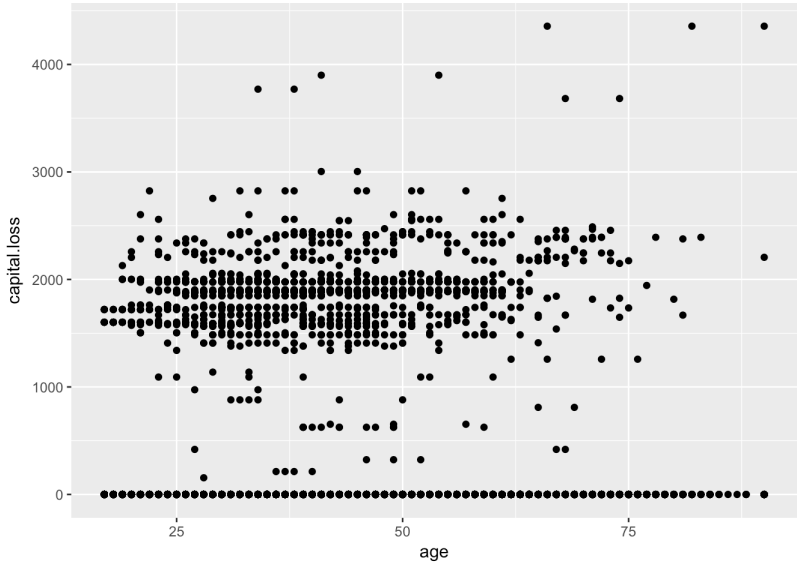


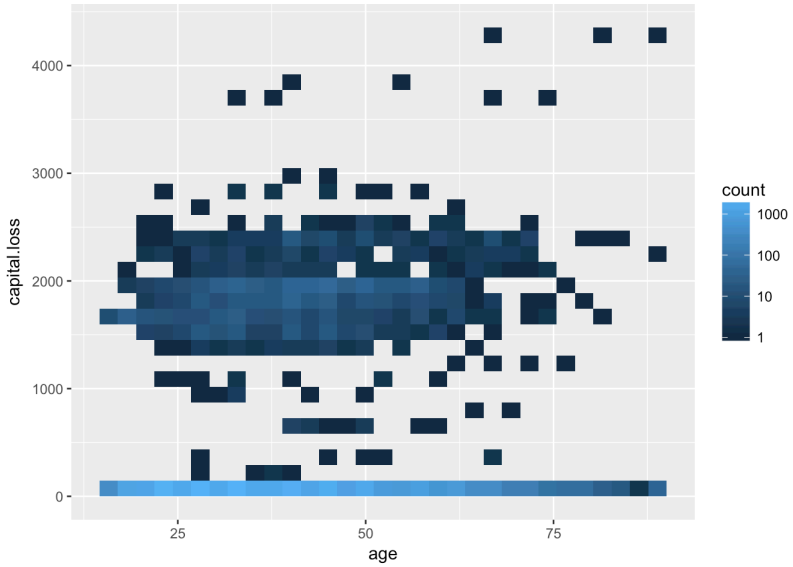




Scatter plot

- Overplotting
- point vs. bin2d





Line chart

- identity vs. summary
- line vs. smooth