Visualizing uncertainty

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Week 7

Data viz in the wild

Cassie

Amy

Diana

Errol and Mandi on deck

Agenda

- Finish up plot refinement slides
- Common ways of visualizing uncertainty
    - And how to implement them with {ggplot2}
- Framing uncertainty as relative frequencies
    - Discrete probabilities
    - Non–discrete probabilities
- Understanding standard errors
    - Non–standard ways of visualizing SEs
- HOPs (pretty quick)

Agenda (continued)

Assuming we still have time (I think we will), we will also at least introduce **tables**. We probably will not have time for fonts, but I have slides for them as well in case we do.

- Be comfortable with the basics of `gt`
    - create a table
    - format columns
    - create spanner heads
    - etc.
- Understand how to use additional fonts (if you so choose)

Expectations for today

Similar to last class, we will have times for you to practice, and times where I will ask you to follow along.

Please make sure R is up and running.

A quick warning

This will be a little more stats focused than basically any lecture we have through the first three courses of this sequence

Finishing plot refinement

Uncertainty

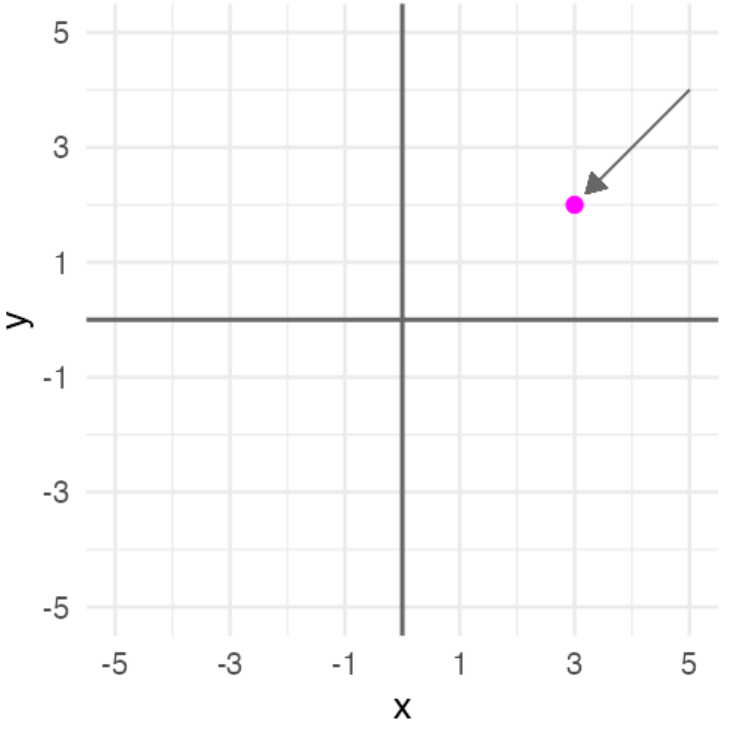
Learning objectives

1. Understand there are lots of different ways to visualize uncertainty, and the best method may often be non–standard.

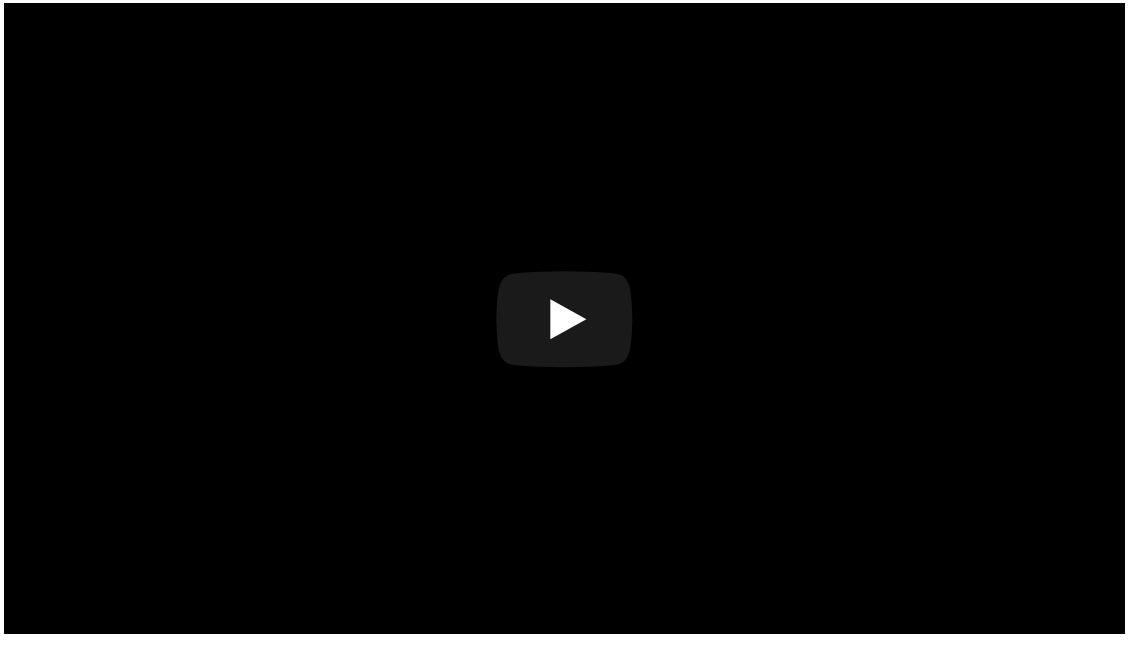
2. Understand how to implement basic methods, and the resources available to you to implement more advanced methods

The primary problem

- When we see a point on a plot, we interpret it as **THE** value.



Let's have Dr. Kay explain

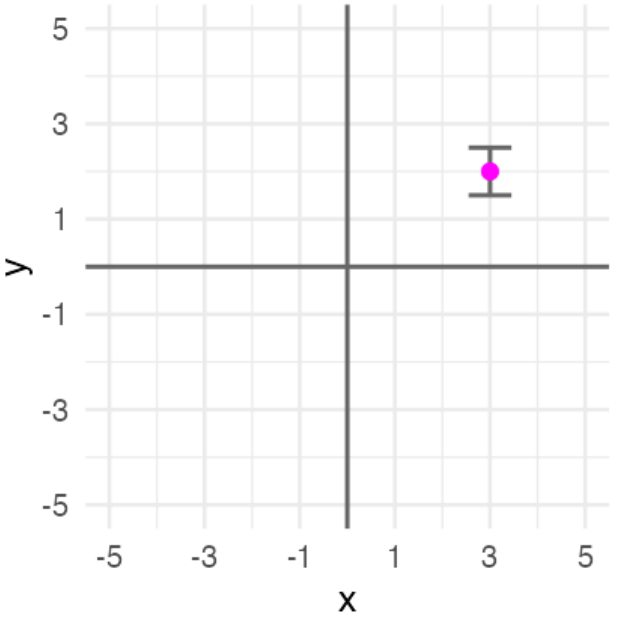


Some secondary problems

- We're not great at understanding probabilities
- We regularly round probabilities to 100% or 0%
- As probabilities move to the tails, we're generally worse

How do we typically communicate uncertainty?

Error bars



How?

Vertical error bars

`geom_errorbar`

- Requires `ymin` and `ymax` aesthetics
- You have to supply these – no calculation for you

Horizontal error bars

`geom_errorbarh`

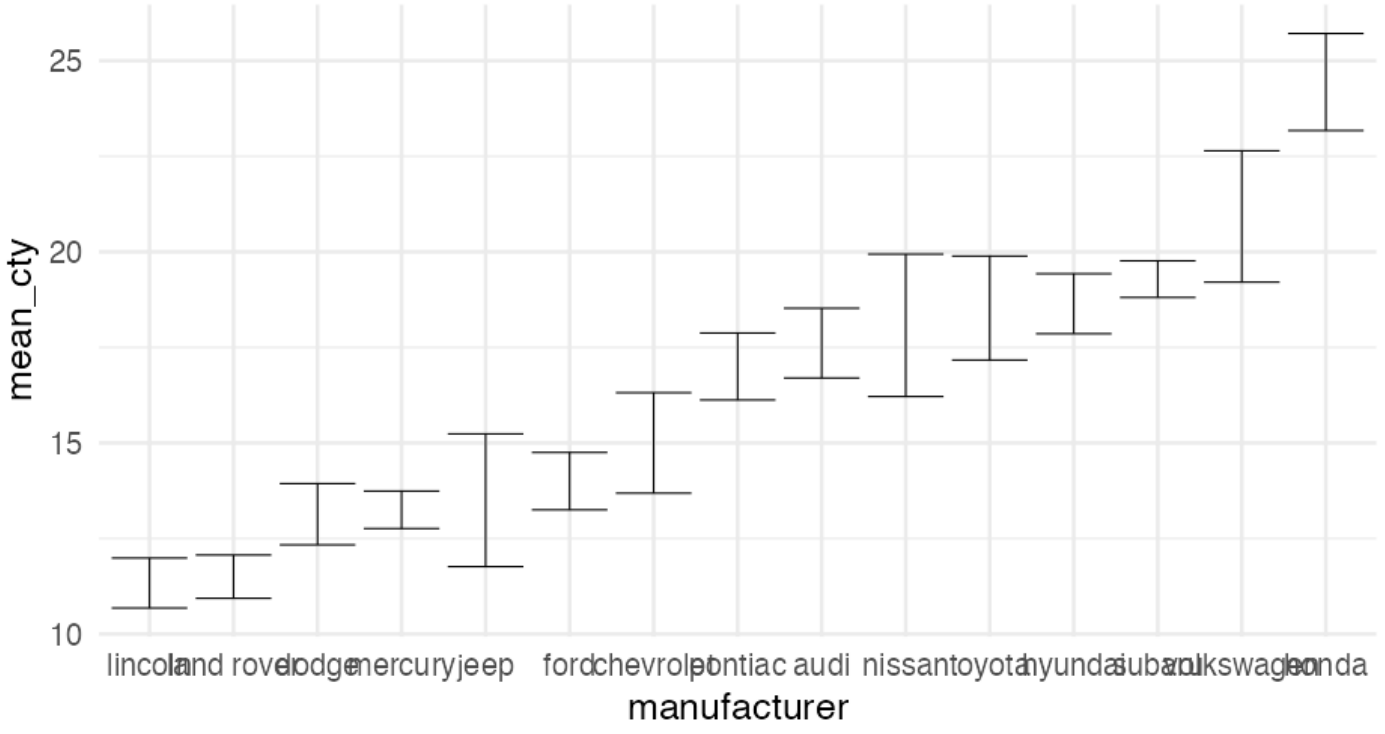
- Requires `xmin` and `xmax`

Example

```
mpg_by_man <- mpg %>%
  group_by(manufacturer) %>%
  summarize(mean_cty = mean(cty),
            se_cty = sd(cty) / sqrt(n()))

head(mpg_by_man)
```

```
## # A tibble: 6 × 3
##   manufacturer mean_cty    se_cty
##   <chr>           <dbl>     <dbl>
## 1 audi         17.61111 0.4653967
## 2 chevrolet    15       0.6710383
## 3 dodge        13.13514 0.4085464
## 4 ford         14       0.3829708
## 5 honda        24.44444 0.6478835
## 6 hyundai      18.64286 0.4006470
```

```
mpg_by_man %>%
  mutate(manufacturer = fct_reorder(manufacturer, mean_cty)) %>%
  ggplot(aes(manufacturer, mean_cty)) +
  geom_errorbar(
    aes(ymin = mean_cty + qnorm(0.025) * se_cty,
        ymax = mean_cty + qnorm(0.975) * se_cty)
  )
```

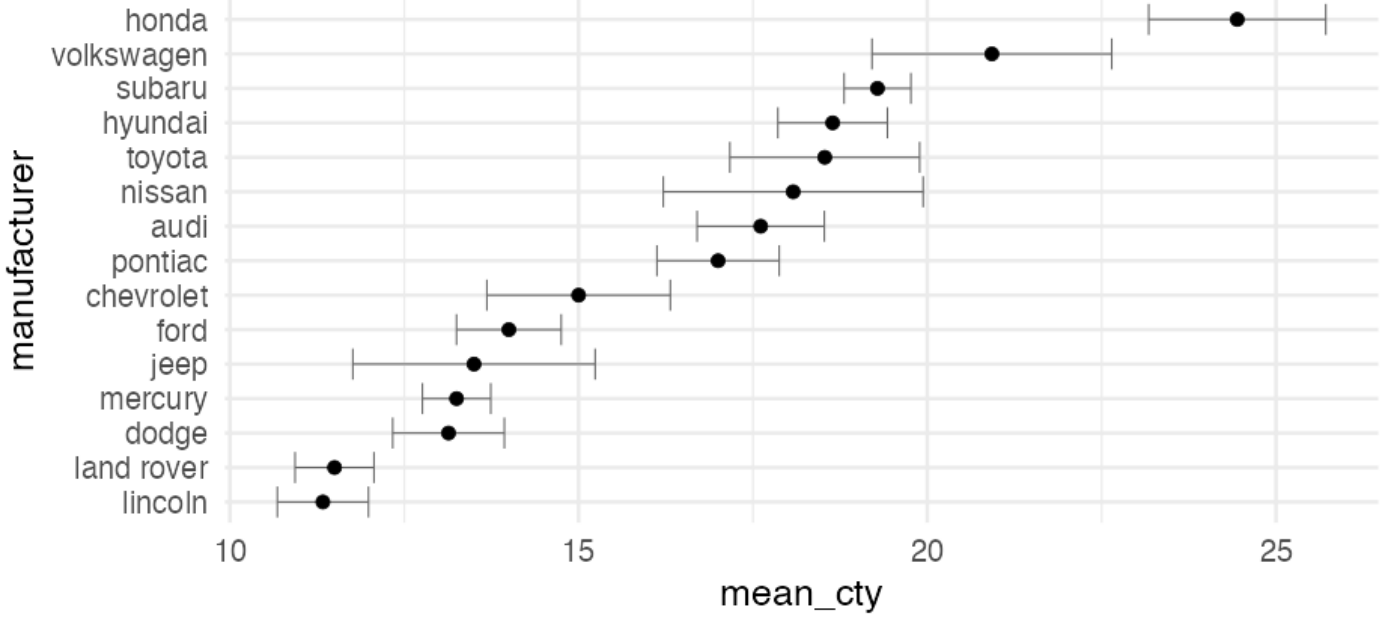


Put points on top

Not under

```
mpg_by_man %>%
  mutate(manufacturer = fct_reorder(manufacturer, mean_cty)) %>%
  ggplot(aes(manufacturer, mean_cty)) +
    geom_errorbar(
      aes(ymin = mean_cty + qnorm(0.025) * se_cty,
          ymax = mean_cty + qnorm(0.975) * se_cty)
    ) +
   geom_point()
```

```
mpg_by_man %>%
  mutate(manufacturer = fct_reorder(manufacturer, mean_cty)) %>%
  ggplot(aes(mean_cty, manufacturer)) +
    geom_errorbarh(
      aes(xmin = mean_cty - 1.96 * se_cty,
          xmax = mean_cty + 1.96 * se_cty),
      color = "gray40"
    ) +
   geom_point()
```



Practice

- Use the Palmer penguins dataset
- Plot the mean `bill_length_mm` for each species with 95% confidence intervals

```
library(palmerpenguins)
penguins
```

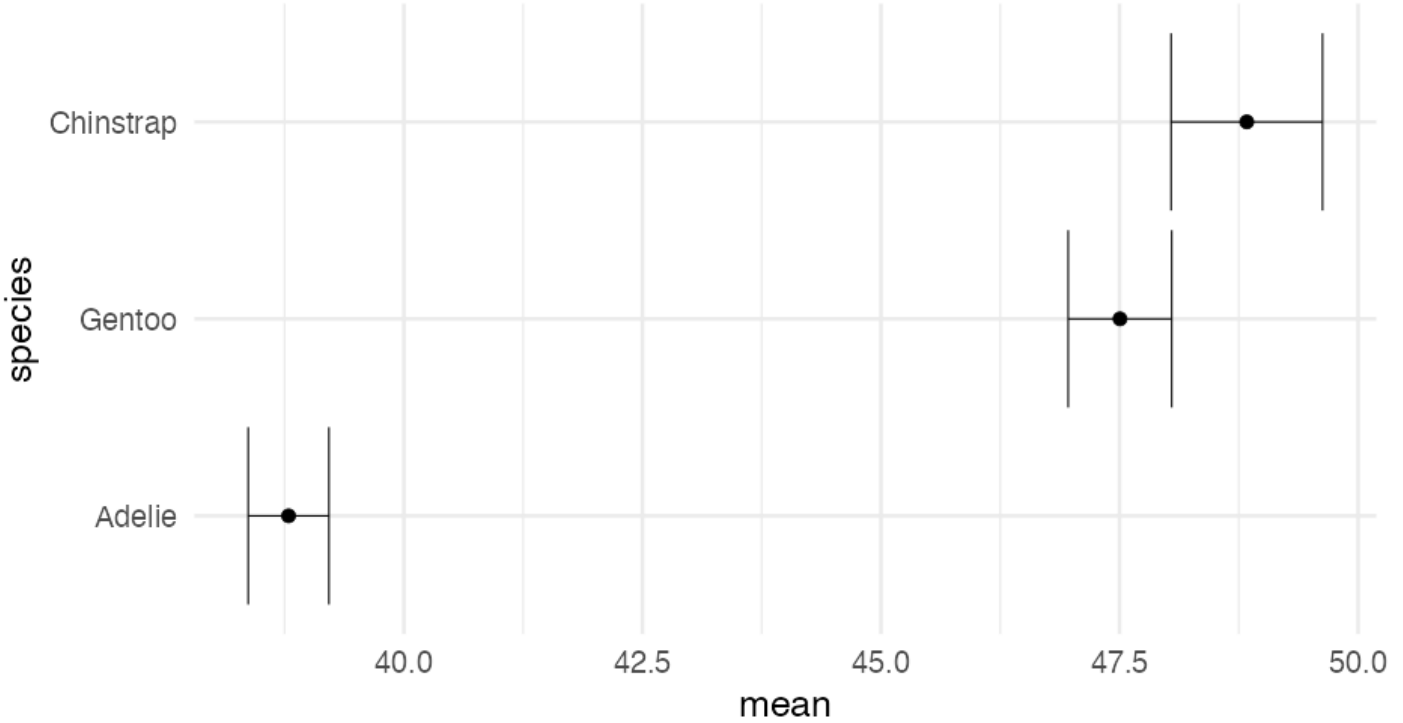
```
## # A tibble: 344 × 8
##   species island    bill_length_mm bill_depth_mm
##   <fct>   <fct>              <dbl>         <dbl>
## 1 Adelie  Torgersen           39.1          18.7
## 2 Adelie  Torgersen           39.5          17.4
## 3 Adelie  Torgersen           40.3          18
## 4 Adelie  Torgersen           NA            NA
## 5 Adelie  Torgersen           36.7          19.3
## 6 Adelie  Torgersen           39.3
## # … with 338 more rows, and 4 more variable
## #   flipper_length_mm <int>, body_mass_g <i
## #   sex <fct>, year <int>
```

05:00

Solution

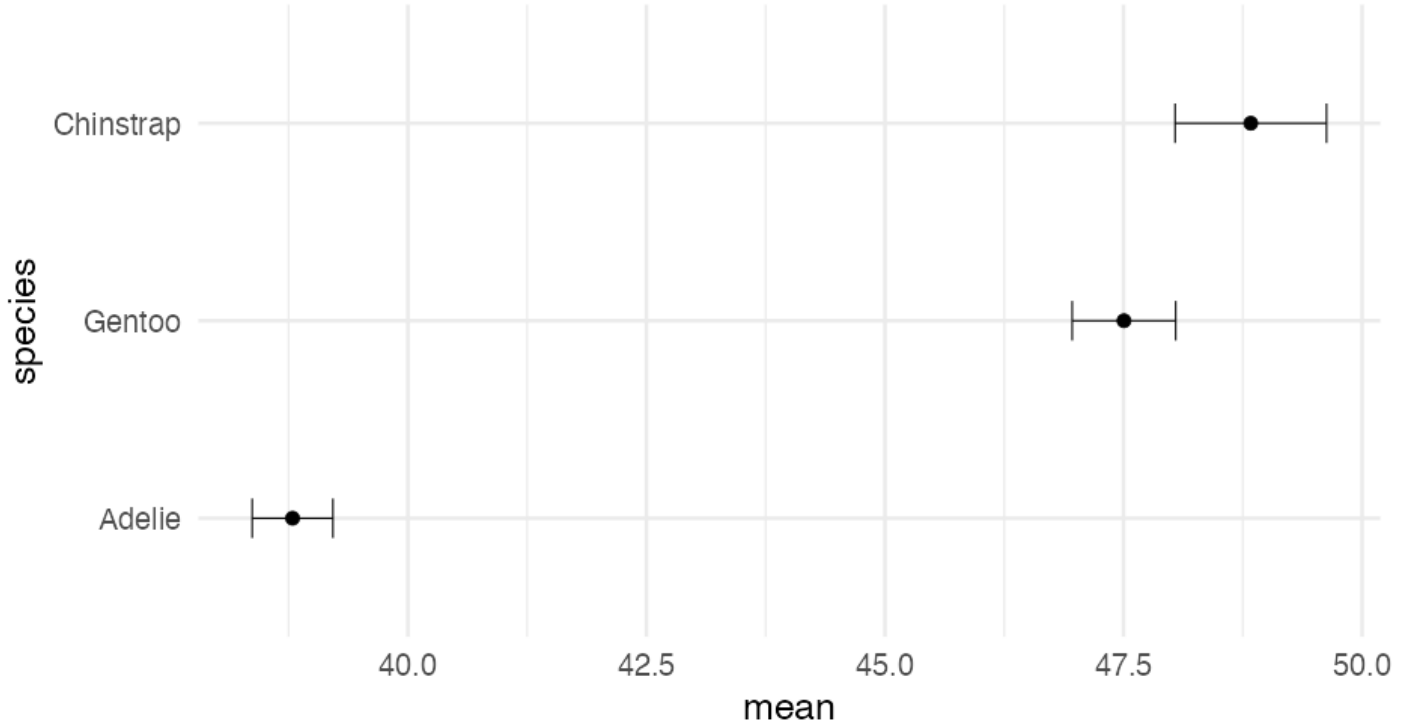
Or one possible solution

```
mn_se <- penguins %>%
  group_by(species) %>%
  summarize(
    mean = mean(bill_length_mm, na.rm = TRUE),
    se = sd(bill_length_mm, na.rm = TRUE) / sqrt(n()),
    lower = mean + qnorm(0.025) * se,
    upper = mean + qnorm(0.975) * se,
  ) %>%
  mutate(species = fct_reorder(species, mean))

ggplot(mn_se, aes(mean, species)) +
  geom_errorbarh(aes(xmin = lower, xmax = upper)) +
  geom_point()
```


Chinstrap
Gentoo
Adelie
species
40.0
42.5
45.0
47.5
50.0
mean

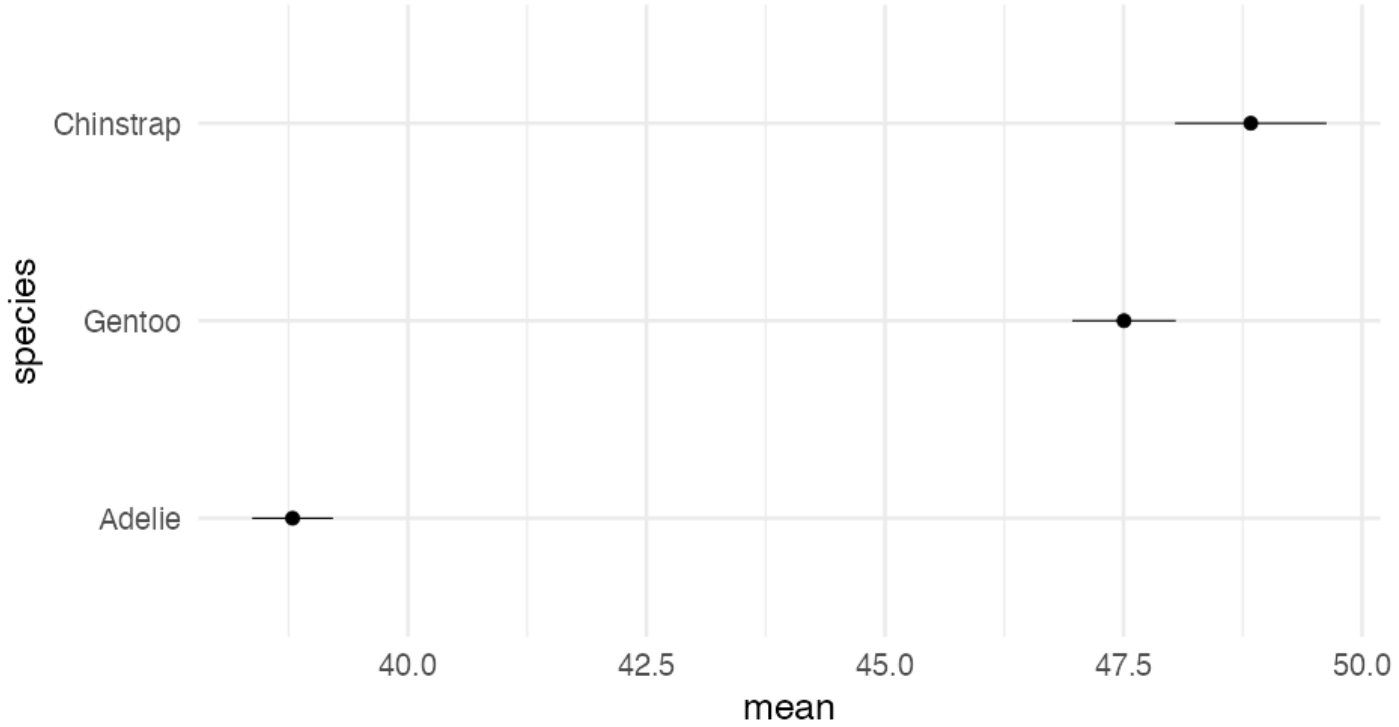
Change the height

```
ggplot(mn_se, aes(mean, species)) +
  geom_errorbarh(aes(xmin = lower, xmax = upper), height = 0.2) +
  geom_point()
```



Slight variant

```
ggplot(mn_se, aes(mean, species)) +
  geom_linerange(aes(xmin = lower, xmax = upper)) +
  geom_point()
```



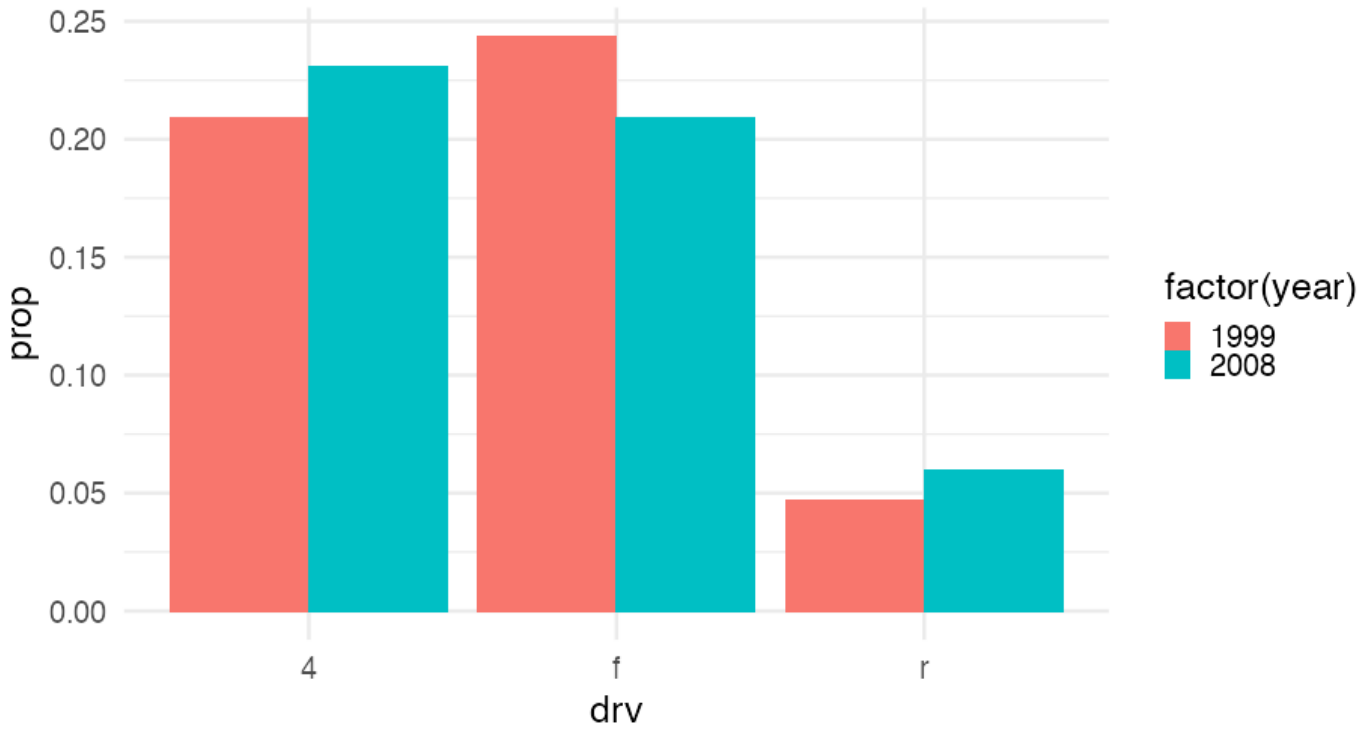
Dodging

```
props <- mpg %>%
  count(drv, year) %>%
  mutate(prop = n / sum(n),
         prop_se = sqrt((prop * (1 - prop)) / n))

head(props)
```

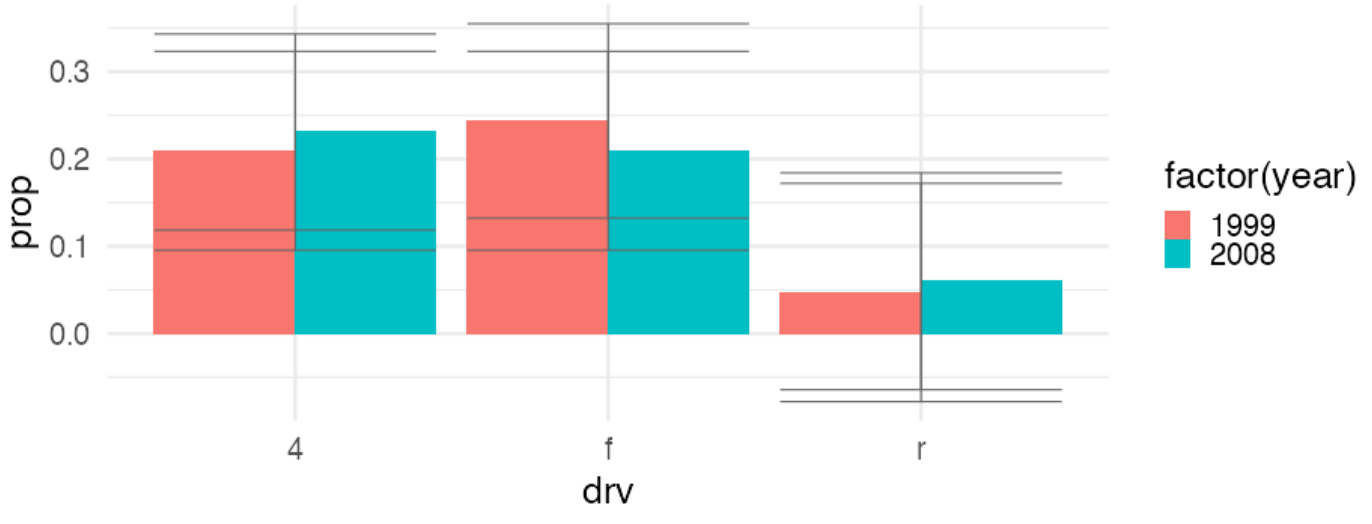
```
## # A tibble: 6 × 5
##   drv    year      n       prop    prop_se
##   <chr> <int> <int>      <dbl>      <dbl>
## 1 4      1999    49 0.2094017  0.05812594
## 2 4      2008    54 0.2307692  0.05733508
## 3 f      1999    57 0.2435897  0.05685528
## 4 f      2008    49 0.2094017  0.05812594
## 5 r      1999    11 0.04700855 0.06381703
## 6 r      2008    14 0.05982906 0.06338631
```

Bar plot

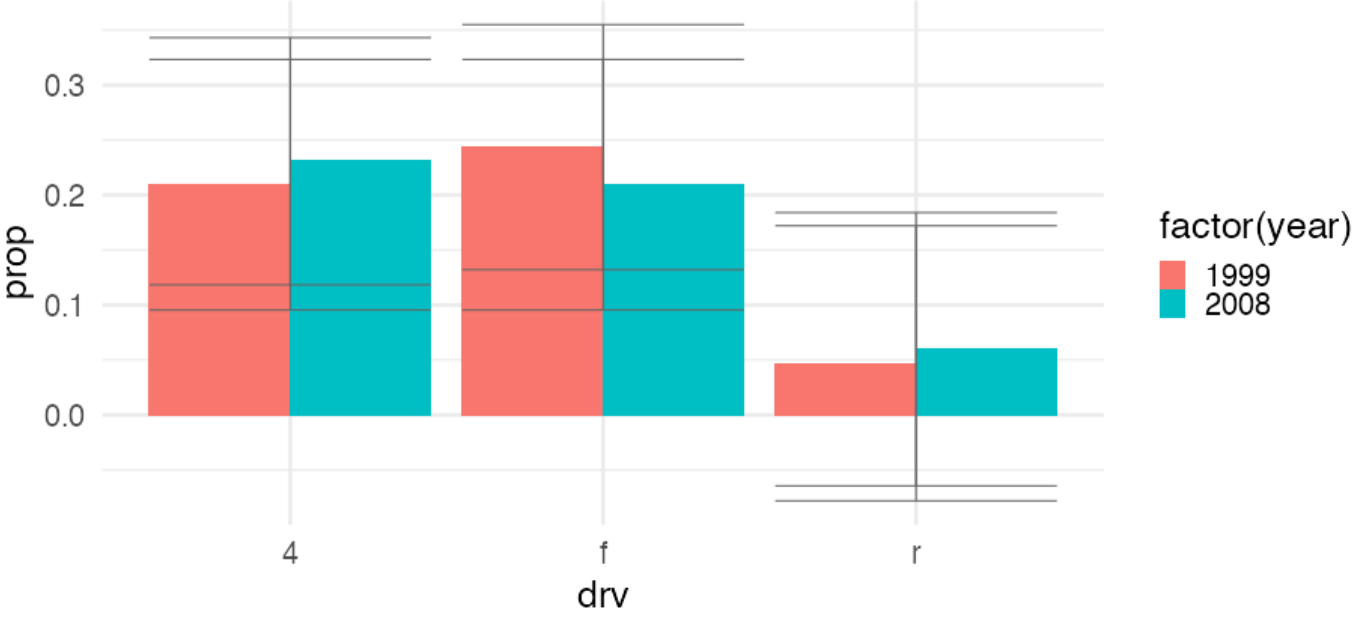
```
ggplot(props, aes(drv, prop)) +
  geom_col(aes(fill = factor(year)), position = "dodge")
```



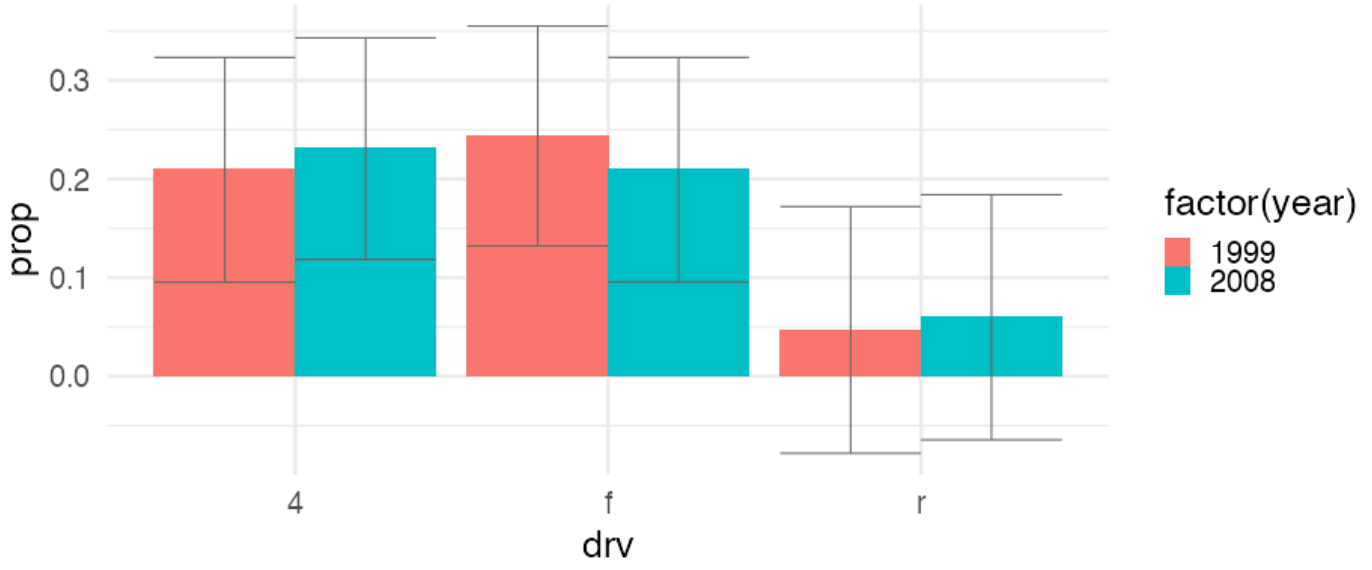
```
ggplot(props, aes(drv, prop)) +
  geom_col(aes(fill = factor(year)), position = "dodge") +
  geom_errorbar(
    aes(ymin = prop - 1.96 * prop_se,
        ymax = prop + 1.96 * prop_se),
    color = "gray40"
  )
```



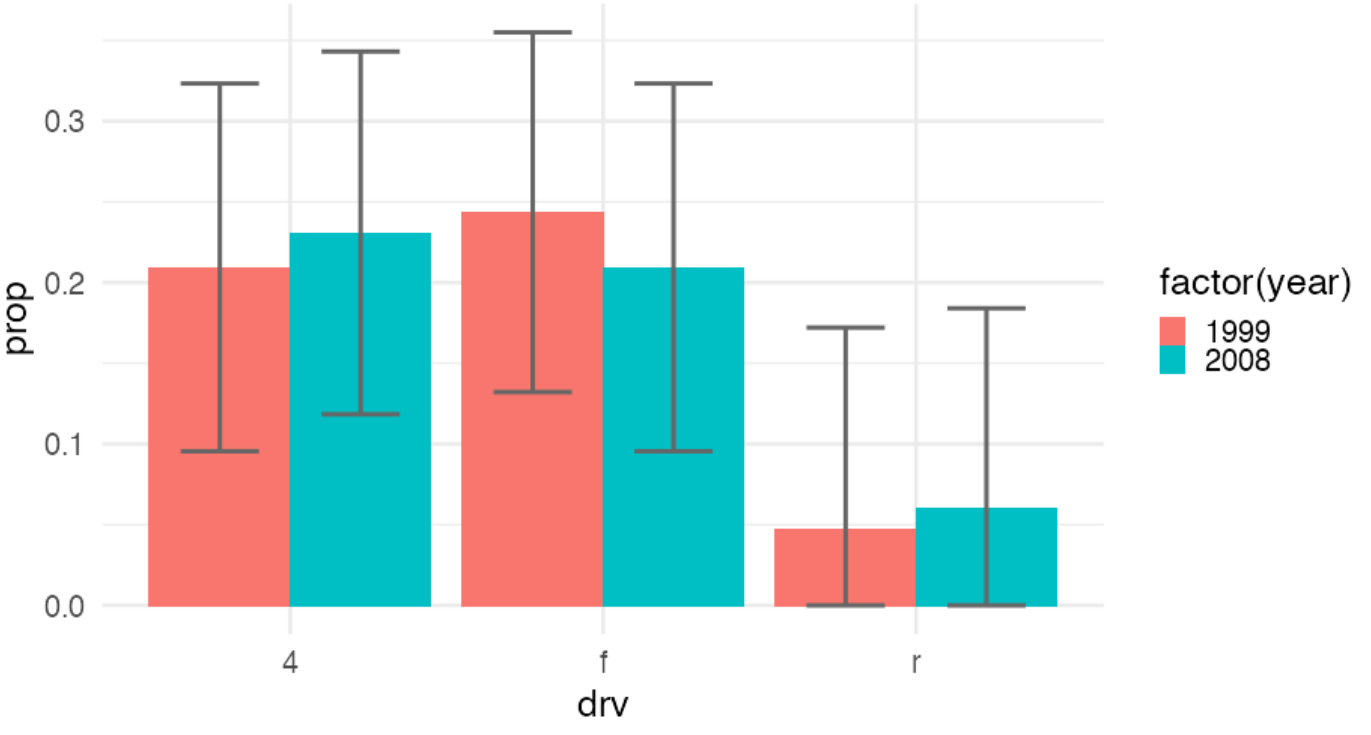
```r
pd <- position_dodge(.9)
ggplot(props, aes(drv, prop)) +
  geom_col(aes(fill = factor(year)), position = pd) +
  geom_errorbar(
    aes(ymin = prop - 1.96 * prop_se,
        ymax = prop + 1.96 * prop_se),
    color = "gray40",
    position = pd
  )
```



```
pd <- position_dodge(.9)
ggplot(props, aes(drv, prop)) +
  geom_col(aes(fill = factor(year)), position = pd) +
  geom_errorbar(
    aes(ymin = prop - 1.96 * prop_se,
        ymax = prop + 1.96 * prop_se,
        group = year
    ),
    color = "gray40",
    position = pd
  )
```



```
pd <- position_dodge(.9)
ggplot(props, aes(drv, prop)) +
  geom_col(aes(fill = factor(year)), position = pd) +
  geom_errorbar(
    aes(
      ymin = ifelse(
        prop - 1.96 * prop_se < 0,
        0,
        prop - 1.96*prop_se
      ),
      ymax = prop + 1.96 * prop_se,
      group = year
    ),
    color = "gray40",
    position = pd,
    width = 0.5,
    size = 1.4
  )
```


0.3
0.2
0.1
0.0
prop
4
f
r
drv
factor(year)
1999
2008

Explain error bars

Error bars could represent any of the following

- Standard deviation (of the data)
- Standard error (of the estimate)
- Confidence interval (of the estimate)

Possibly through a caption, make sure your audience knows what your represent.

If Confidence intervals, state the interval size (e.g., 68%, 90%, 95%)

Thinking about uncertainty

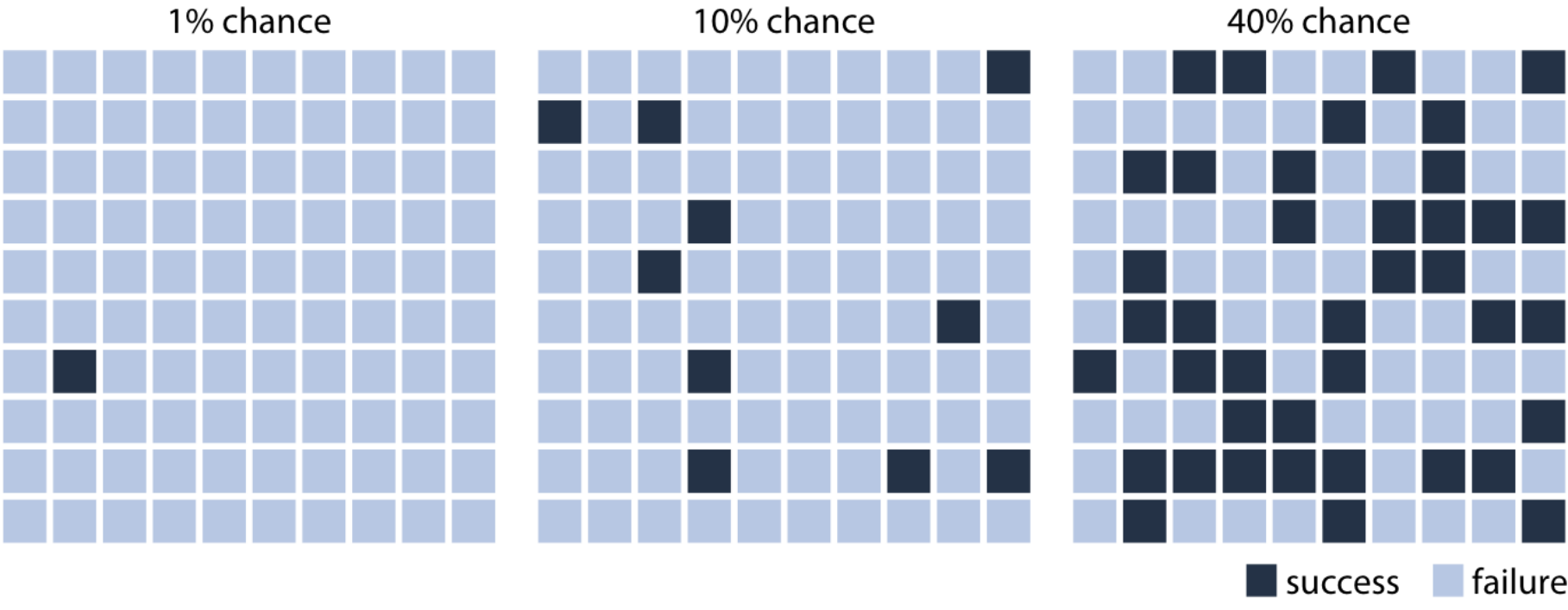
Uncertainty means exactly what it sounds like – we are not 100% sure.

- We are nearly always uncertain of future events (forecasting)
- We can also be uncertain about past events
  - I saw a parked car at 8 AM, but the next time I looked at 2PM it was gone. What time did it leave?

Quantifying uncertainty

- We quantify our uncertainty mathematically using probability
- Framing probabilities as frequencies is generally more intuitive

Framing a single uncertainty


1% chance
10% chance
40% chance
success
failure

How do we make these?

- Start out by making a grid

```
grid <- expand.grid(x = 1:20, y = 1:20)
head(grid)
```

```
##   x y
## 1 1 1
## 2 2 1
## 3 3 1
## 4 4 1
## 5 5 1
## 6 6 1
```

```
tail(grid)
```

```
##       x  y
## 395 15 20
## 396 16 20
## 397 17 20
## 398 18 20
## 399 19 20
## 400 20 20
```

Look at the grid

```
ggplot(grid, aes(x, y)) +
  geom_tile(color = "gray40",
            fill = "white") +
  theme_void()
```

Create occurrence rate

- For each sequence of x, create a variable that has the given occurence rate

How?

- Plenty of options, here's one

Please follow along

Consider 10%

```
# create your grid
grid <- expand.grid(x = 1:20, y = 1:20)

# n to sample
n_sample <- nrow(grid) * .10

set.seed(86753098)
samp <- sample(seq_len(nrow(grid)), n_sample)
head(samp)
```

```
## [1] 318 134 180 283 177 248
```

```
length(samp)
```

```
## [1] 40
```

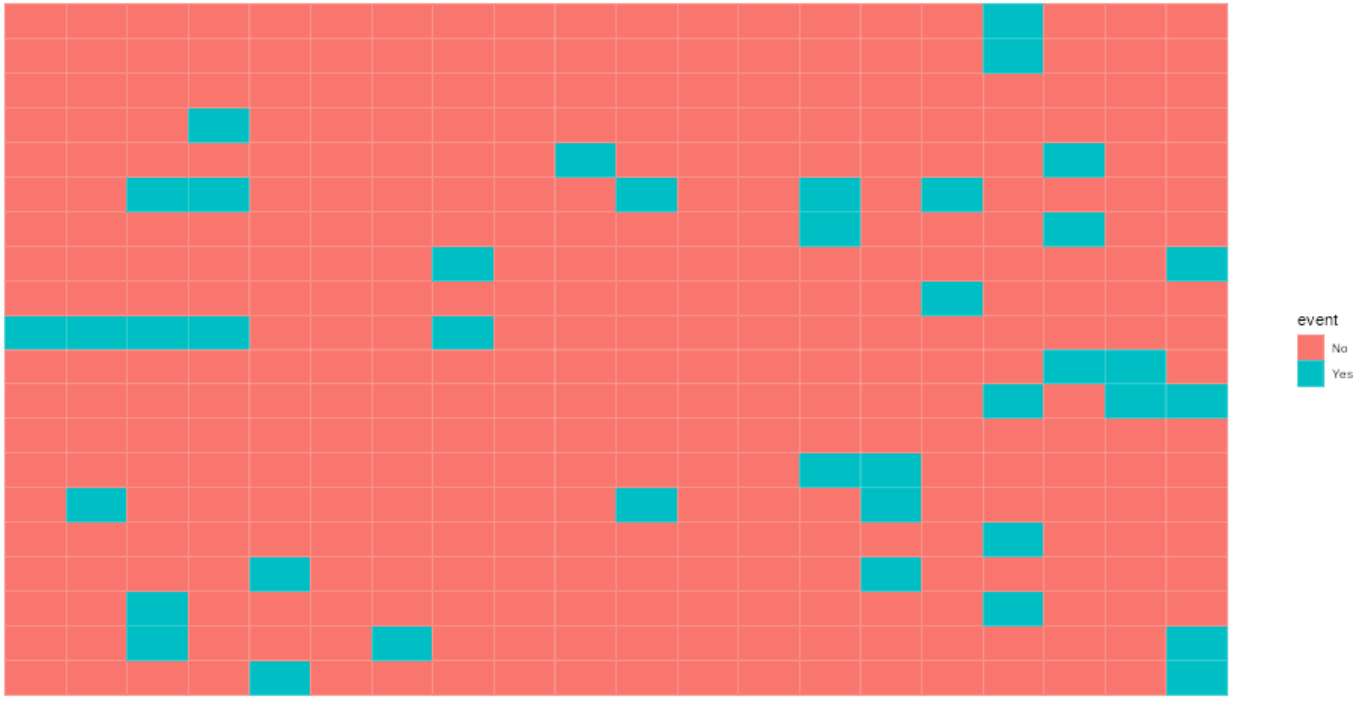
Create the variable

```
grid <- grid %>%
  rownames_to_column("row_id") %>%
  mutate(event = ifelse(row_id %in% samp, "Yes", "No"))
head(grid)
```

```
##   row_id x y event
## 1      1 1 1    No
## 2      2 2 1    No
## 3      3 3 1    No
## 4      4 4 1    No
## 5      5 5 1   Yes
## 6      6 6 1    No
```

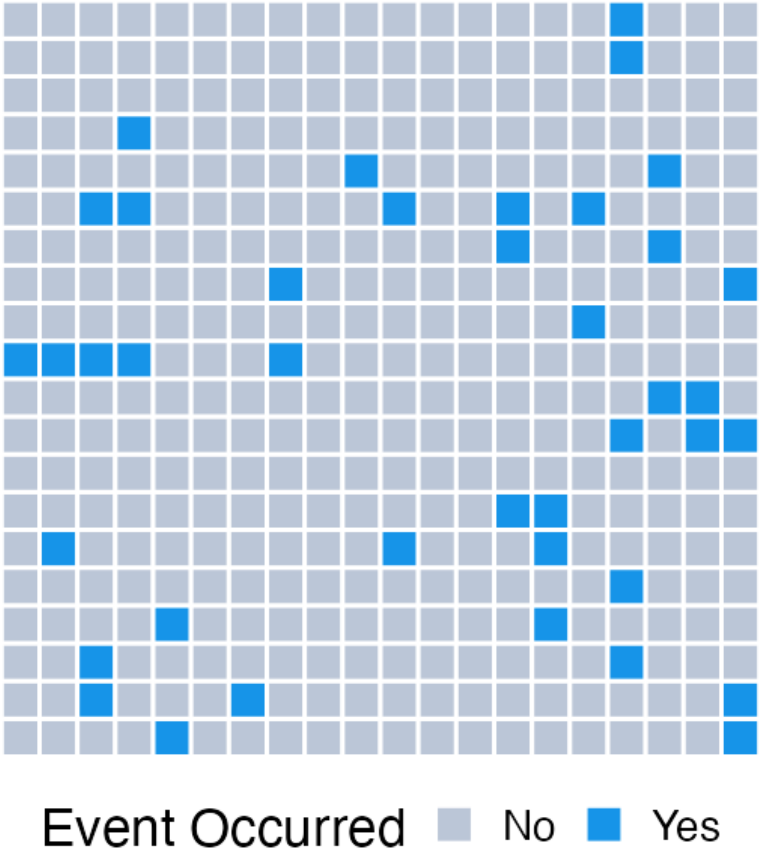
Fill in

```
ggplot(grid, aes(x, y)) +
  geom_tile(aes(fill = event), color = "white") +
  theme_void()
```

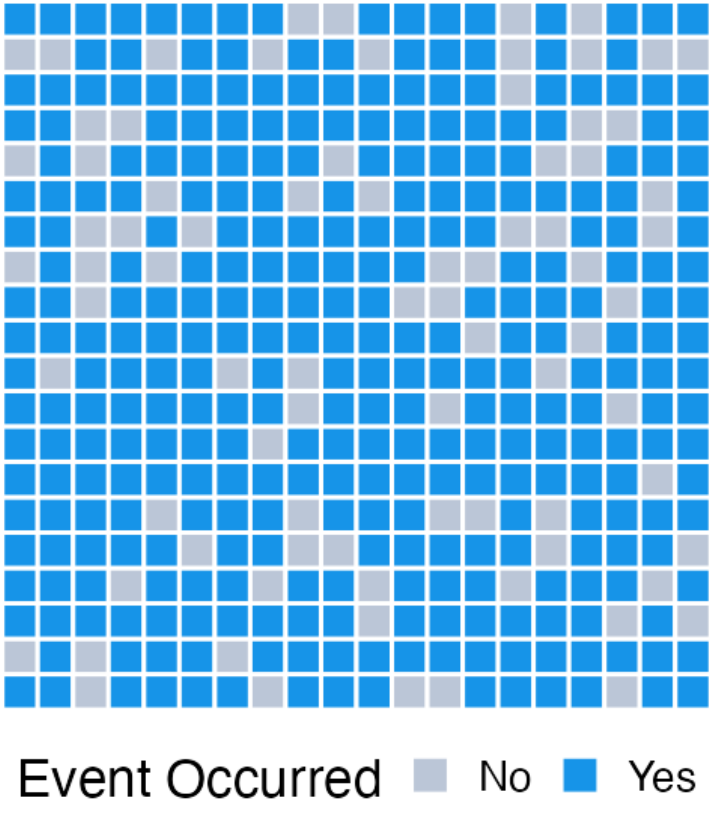


Customize

```
library(colorspace)
ggplot(grid, aes(x, y)) +
  geom_tile(aes(fill = event), color = "white", size = 1.4) +
  scale_fill_manual(
    name = "Event Occurred",
    values = c(
      desaturate(lighten("#1694E8", 0.5), 0.7),
      "#1694E8"
      )
    ) +
  coord_fixed() +
  theme_void() +
  theme(legend.position = c(0.75, 0),
        legend.direction = "horizontal",
        plot.margin = margin(b = 1, unit = "cm"))
```

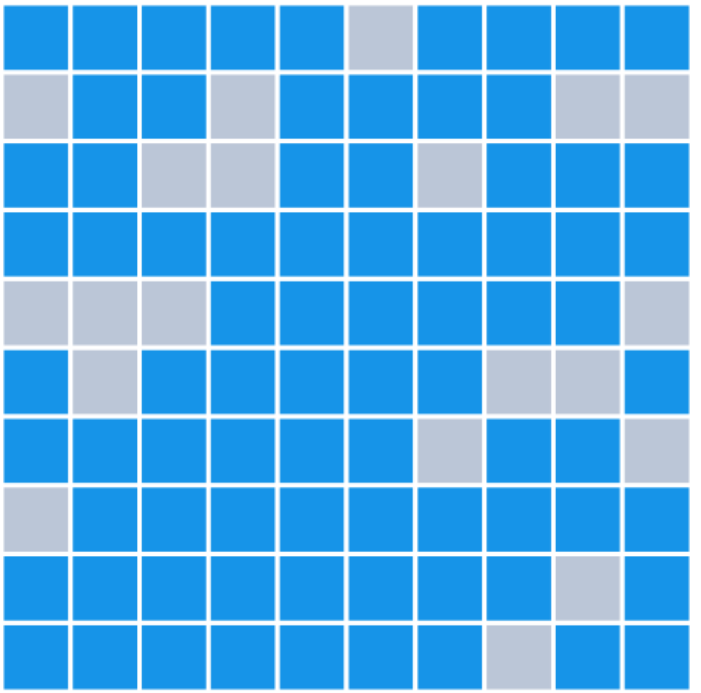

Event Occurred
No
Yes

Chance of rain



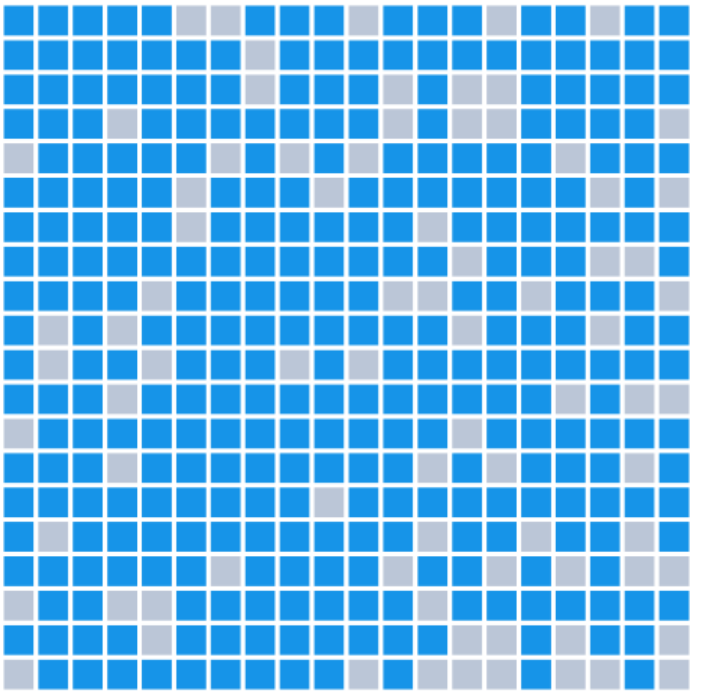
Vary grid size

10 x 10



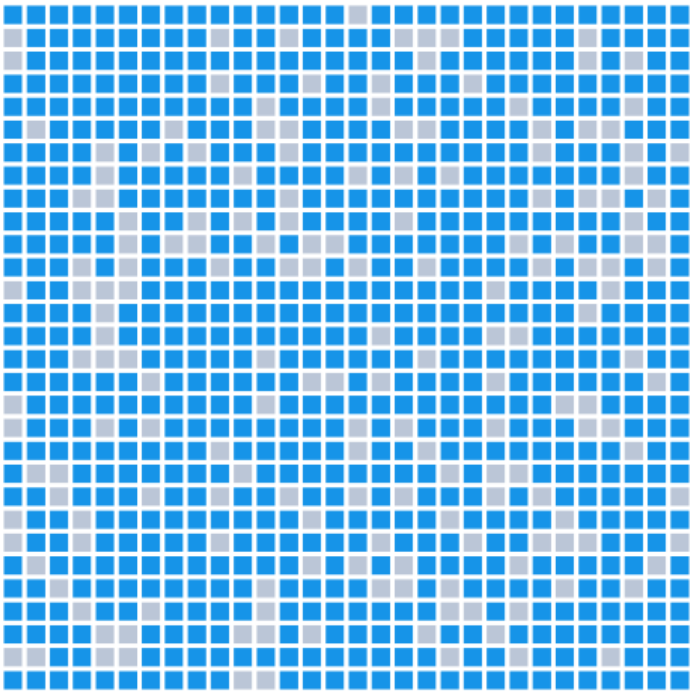
Vary grid size

20 x 20



Vary grid size

30 x 30



Optimal size might depend on your venue

Practice

- Create a new grid showing 41% likelihood of something happening
- Vary the fill colors and grid size
- Compare with a neighbor – what do you like about yours vs. theirs?

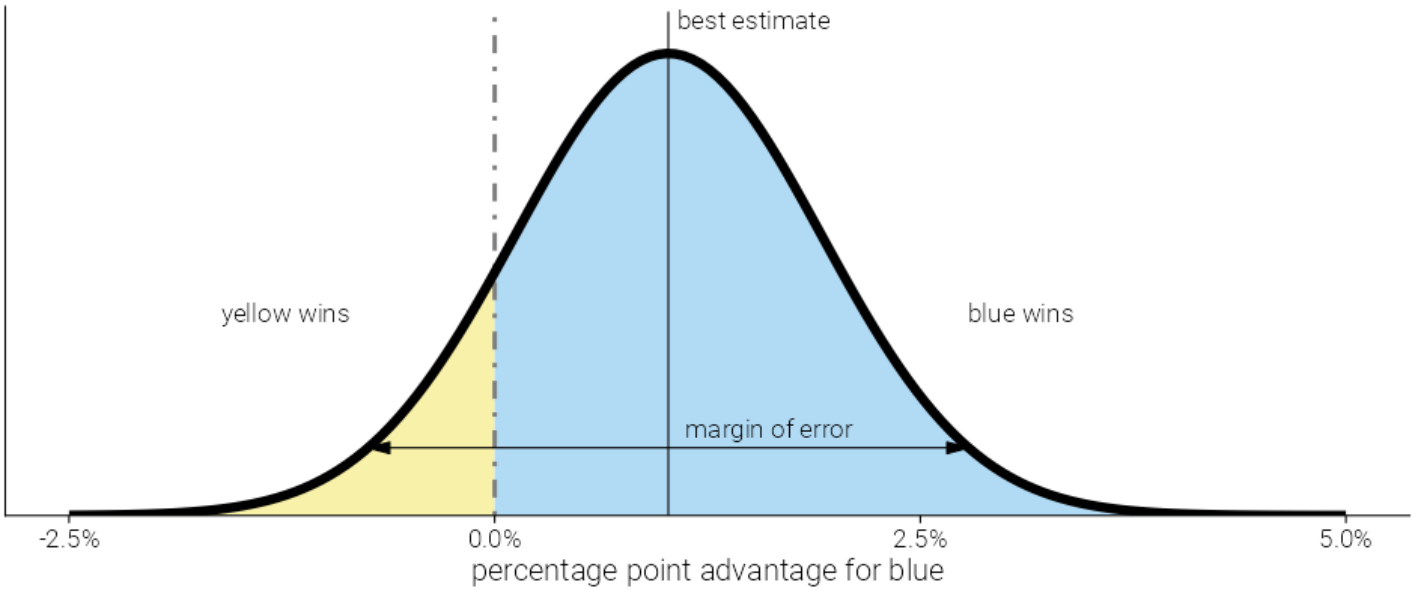
05:00

Non–discrete probabilities

Hypothetical

Blue party has 1% advantage w/ margin of error of 1.76 percentage points

Who will win and **by how much**?



A bit of math

Our distribution was defined by $\mu = 1.02$ and $sd = 0.9$.

- What's the chance the end result is **below zero**? (yellow wins)

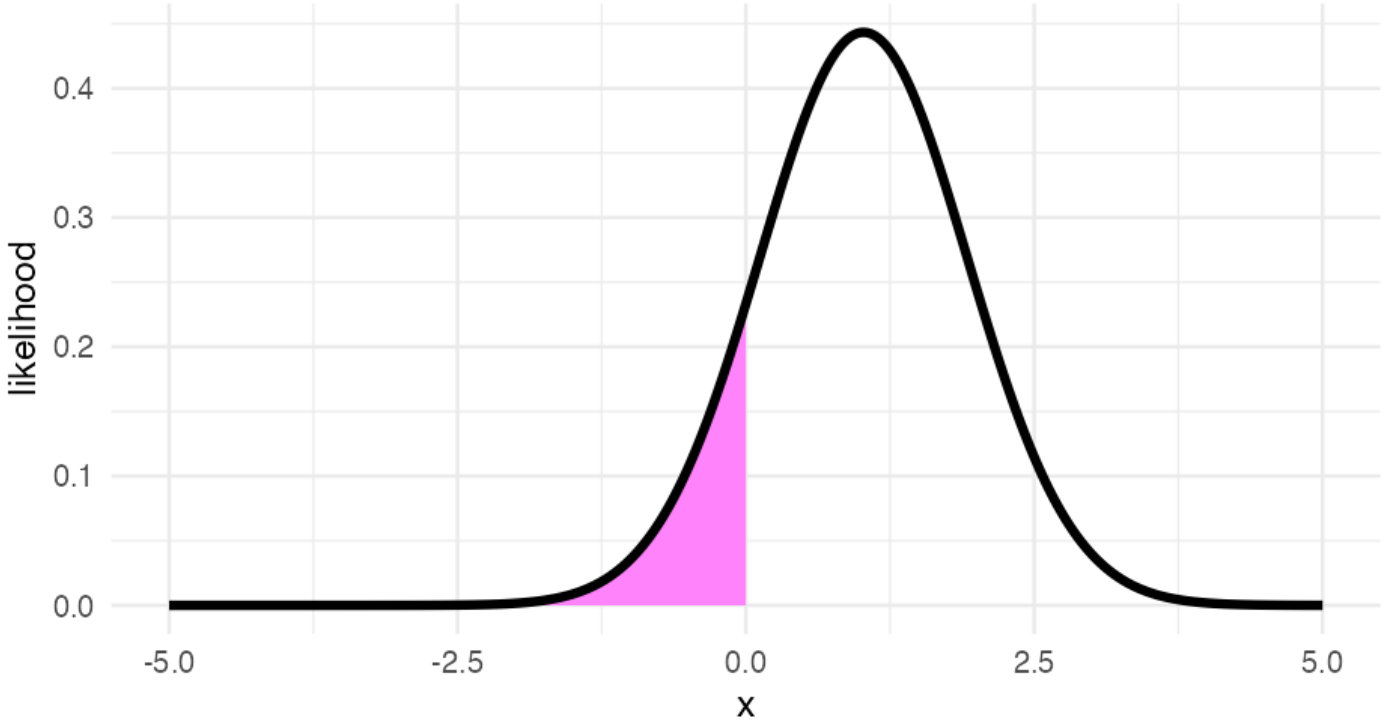
The hard way

Calculate the exact probability

The distribution

```
x <- seq(-5, 5, 0.001) # some sample data
likelihood <- dnorm(x, 1.02, 0.9) # probability of occuring
sim <- data.frame(x, likelihood)

ggplot(sim, aes(x, likelihood)) +
  geom_line(size = 1.2)
```

How do we calculate this portion?



Integrate

```
zab <- filter(sim, x <= 0)
pracma::trapz(zab$x, zab$likelihood)
```

```
## [1] 0.129
```

Easier: Simulate

```
random_draws <- rnorm(1e5, 1.02, 0.9)
table(random_draws > 0) / 1e5
```

```
##
## FALSE  TRUE
## 0.128 0.872
```

Problem

This approach works okay, but...

- We're not great an interpreting probabilities
- Not great at infering a probability from a density

Discretized plot

```
ppoints(50)
```

```
##  [1] 0.01 0.03 0.05 0.07 0.09 0.11 0.13 0.15 0.17
## [10] 0.19 0.21 0.23 0.25 0.27 0.29 0.31 0.33 0.35
## [19] 0.37 0.39 0.41 0.43 0.45 0.47 0.49 0.51 0.53
## [28] 0.55 0.57 0.59 0.61 0.63 0.65 0.67 0.69 0.71
## [37] 0.73 0.75 0.77 0.79 0.81 0.83 0.85 0.87 0.89
## [46] 0.91 0.93 0.95 0.97 0.99
```

```
qnorm(ppoints(50), 1.02, 0.9)
```

```
##  [1] -1.07371 -0.67271 -0.46037 -0.30821 -0.18668
##  [6] -0.08388  0.00625  0.08721  0.16125  0.22989
## [11]  0.29422  0.35504  0.41296  0.46847  0.52195
## [16]  0.57373  0.62408  0.67321  0.72133  0.76861
## [21]  0.81521  0.86126  0.90690  0.95226  0.99744
## [26]  1.04256  1.08774  1.13310  1.17874  1.22479
## [31]  1.27139  1.31867  1.36679  1.41592  1.46627
## [36]  1.51805  1.57153  1.62704  1.68496  1.74578
## [41]  1.81011  1.87875  1.95279  2.03375  2.12388
## [46]  2.22668  2.34821  2.50037  2.71271  3.11371
```

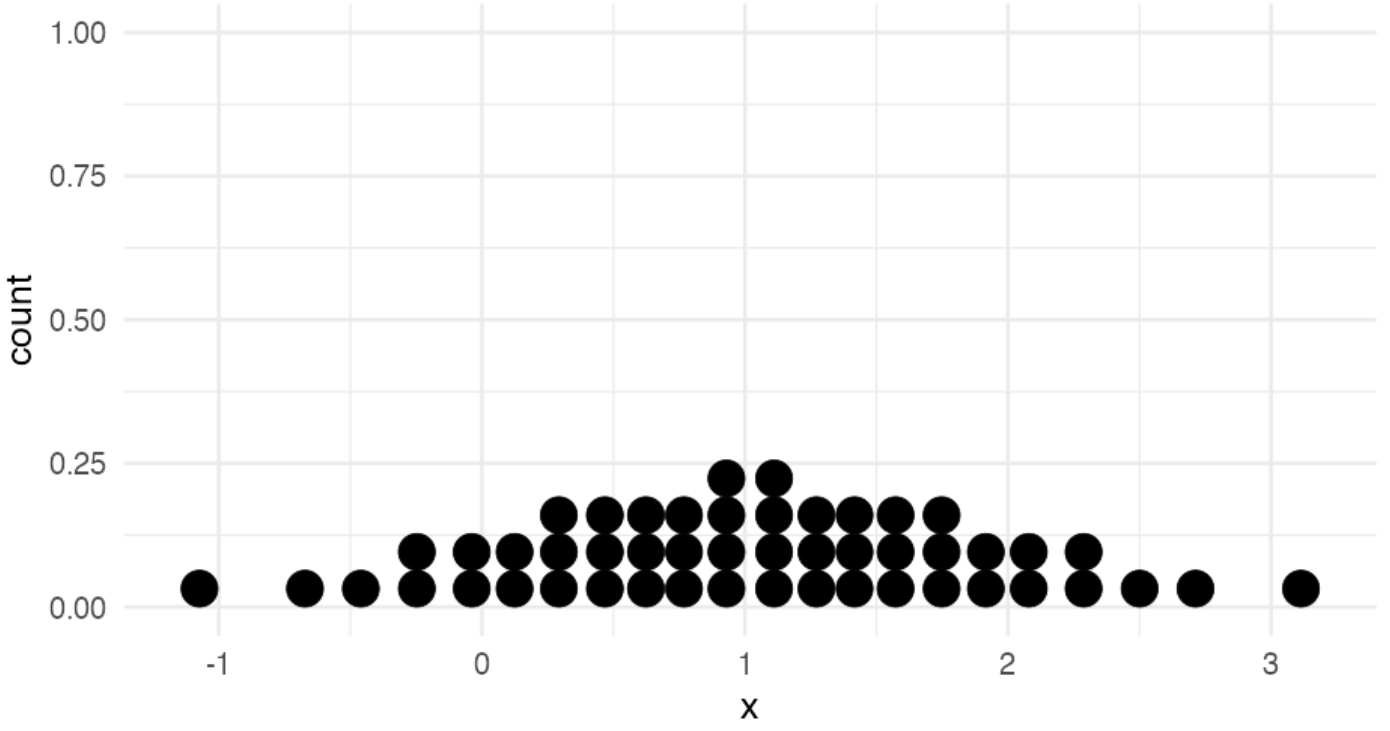
```r
discretized <- data.frame(
  x = qnorm(ppoints(50), 1.02, 0.9)
  ) %>%
  mutate(winner = ifelse(x <= 0, "#b1daf4", "#f8f1a9"))

head(discretized)
```

```
##         x  winner
## 1 -1.0737 #b1daf4
## 2 -0.6727 #b1daf4
## 3 -0.4604 #b1daf4
## 4 -0.3082 #b1daf4
## 5 -0.1867 #b1daf4
## 6 -0.0839 #b1daf4
```

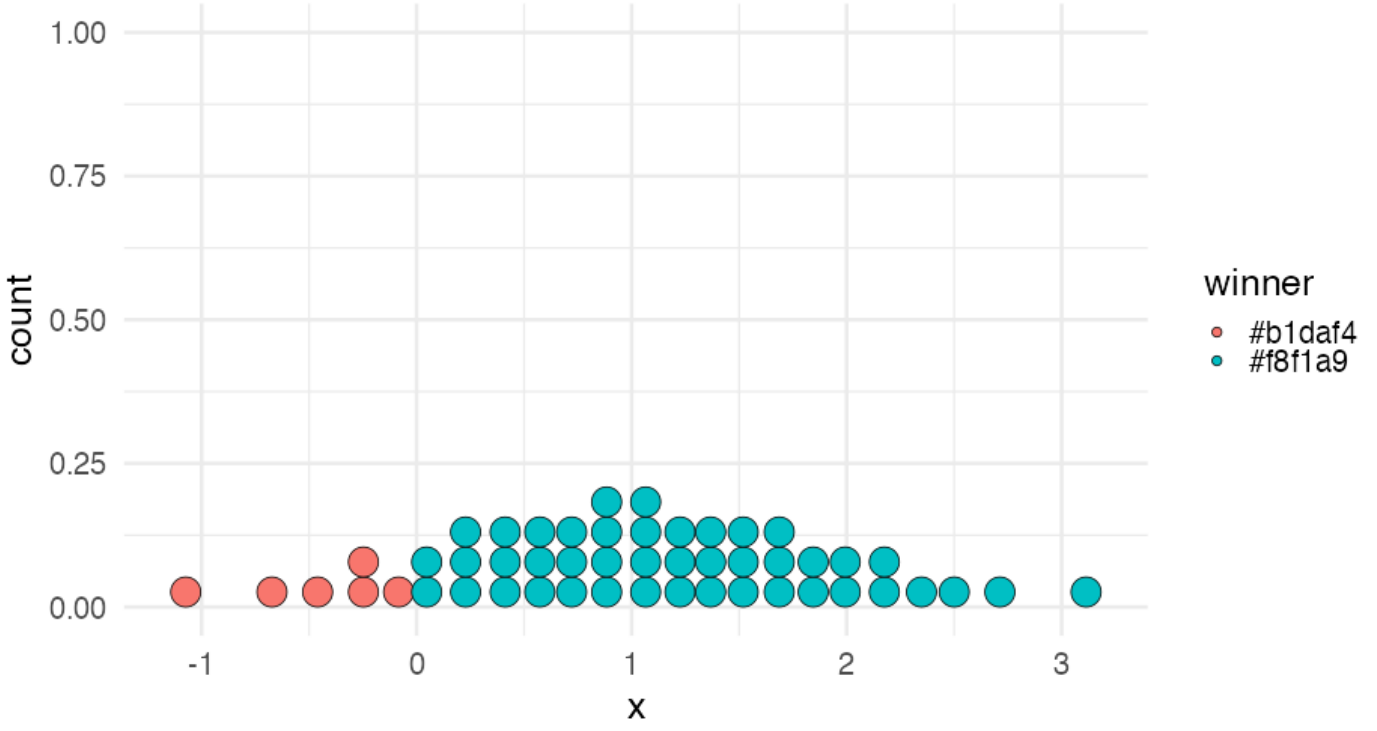
```r
tail(discretized)
```

```
##       x  winner
## 45 2.12 #f8f1a9
## 46 2.23 #f8f1a9
## 47 2.35 #f8f1a9
## 48 2.50 #f8f1a9
## 49 2.71 #f8f1a9
## 50 3.11 #f8f1a9
```

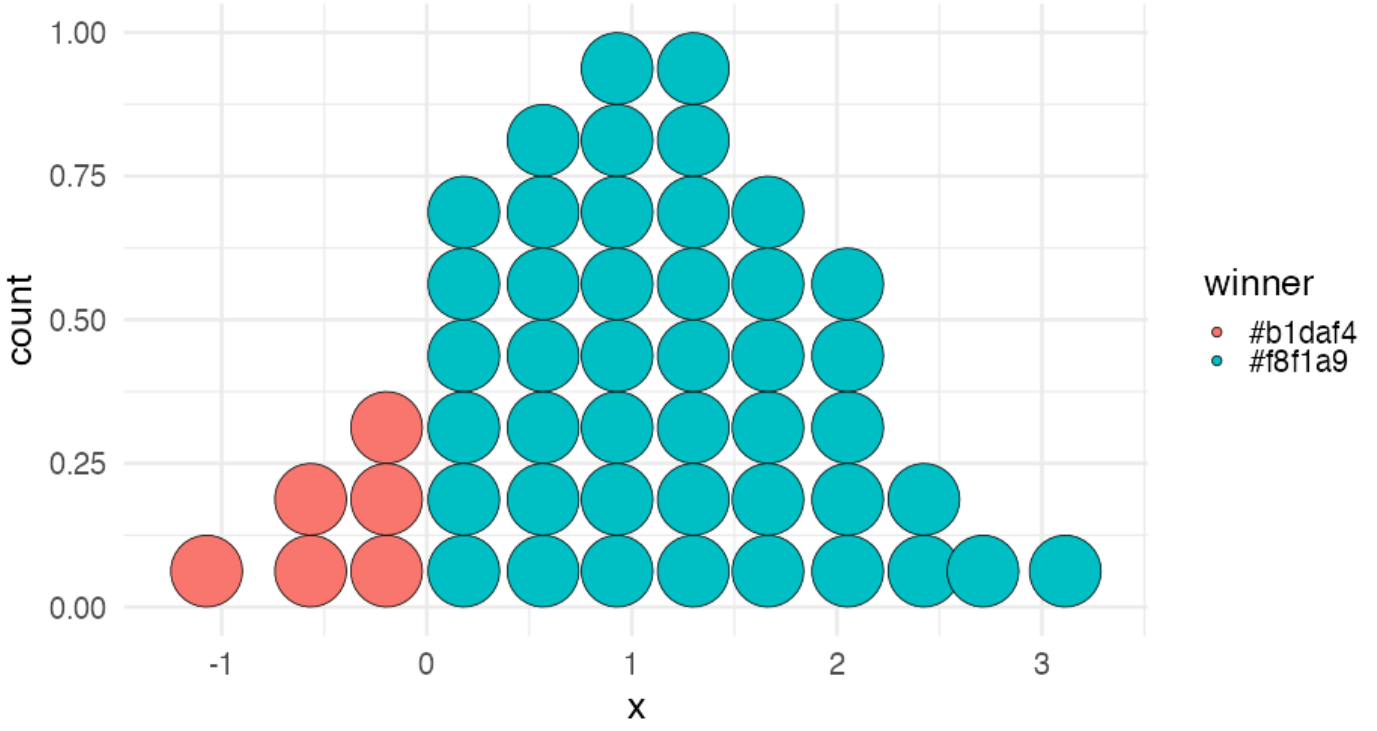
```
ggplot(discretized, aes(x)) +
  geom_dotplot()
```



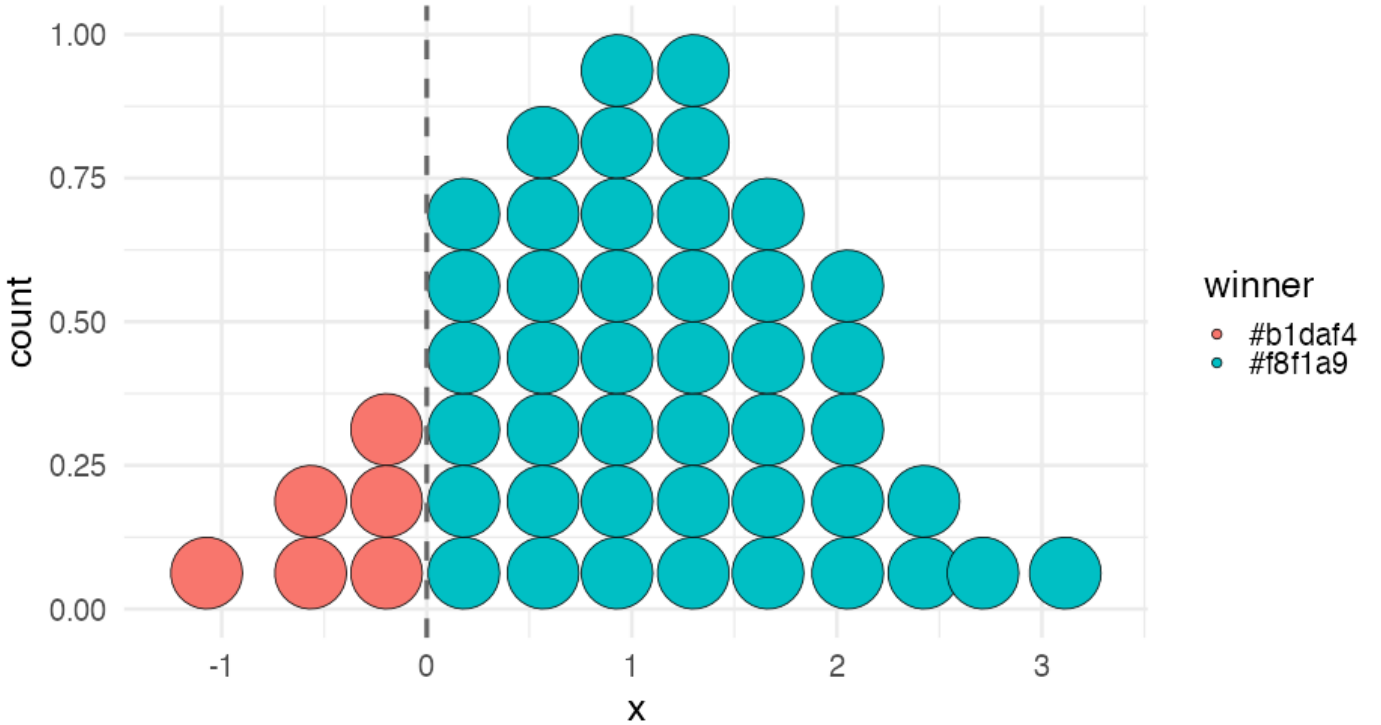
```
ggplot(discretized, aes(x)) +
  geom_dotplot(aes(fill = winner))
```



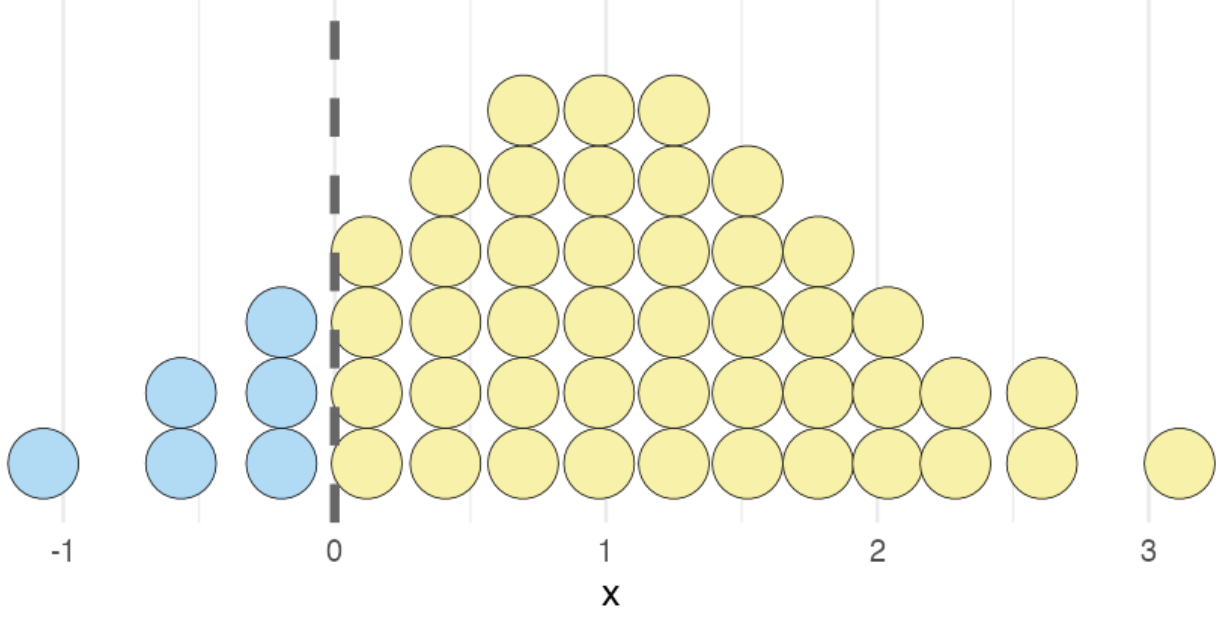
```
ggplot(discretized, aes(x)) +
  geom_dotplot(aes(fill = winner), binwidth = 0.35)
```



```
ggplot(discretized, aes(x)) +
  geom_dotplot(aes(fill = winner), binwidth = 0.35) +
  geom_vline(xintercept = 0,
             color = "gray40",
             linetype = "dashed",
             size = 1.5)
```

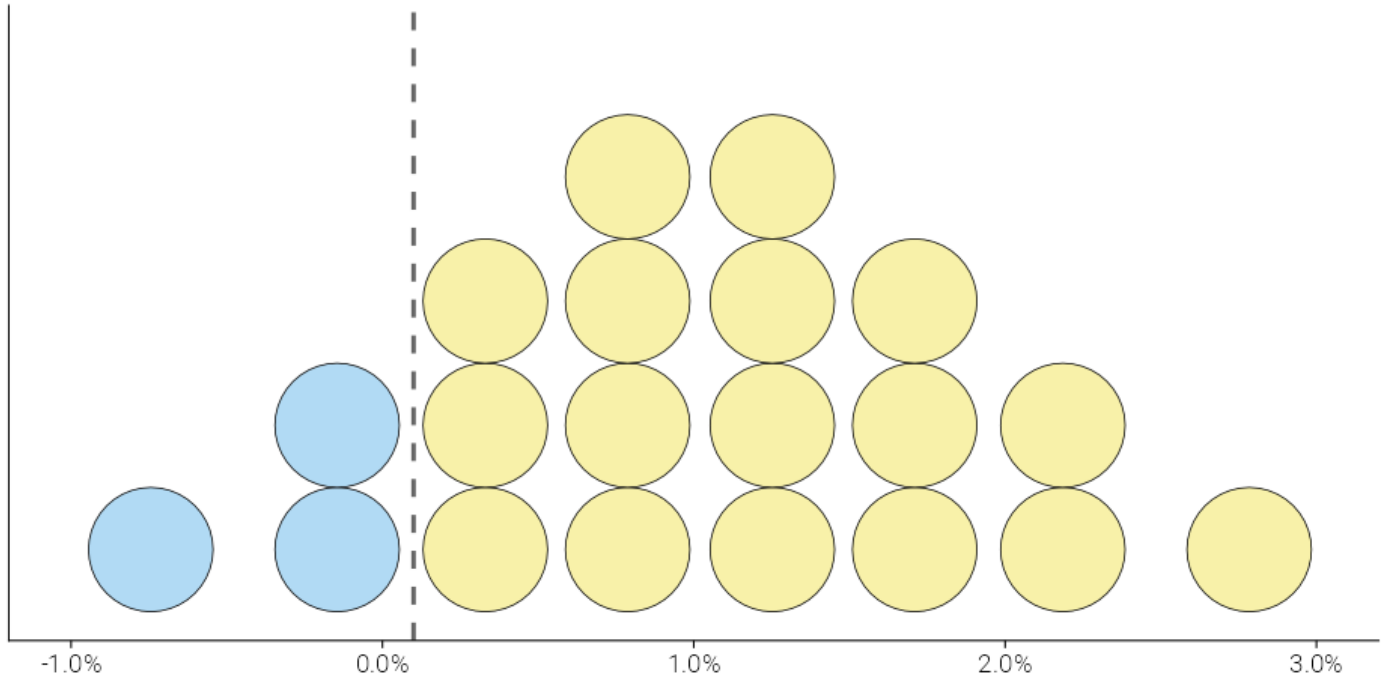


```
ggplot(discretized, aes(x)) +
  geom_dotplot(aes(fill = winner), binwidth = 0.26) +
  geom_vline(xintercept = 0,
             color = "gray40",
             linetype = 2,
             size = 3) +
  scale_fill_identity(guide = "none") +
  scale_y_continuous(name = "",
                     breaks = NULL)
```



Probs too many though

```
discretized2 <- data.frame(
  x = qnorm(ppoints(20), 1.02, 0.9)
  ) %>%
  mutate(winner = ifelse(x <= 0, "#b1daf4", "#f8f1a9"))

ggplot(discretized2, aes(x)) +
  geom_dotplot(aes(fill = winner), binwidth = 0.4) +
  geom_vline(
    xintercept = 0.1,
    color = "gray40",
    linetype = 2,
    size = 1.4) +
  scale_fill_identity(guide = "none") +
  scale_x_continuous(
    name = "",
    limits = c(-1, 3),
    labels = scales::percent_format(scale = 1)
  ) +
  theme_dviz_open(20, font_family = "Roboto Light") +
  scale_y_continuous(breaks = NULL,
                     name = "") +
  labs(caption = "Each ball represents 5% probability")
```


-1.0%
0.0%
1.0%
2.0%
3.0%
Each ball represents 5% probability

Uncertainty of point estimates

Quick (hopefully) review

- What is a standard error?
- Standard deviation of the sampling distribution
- What is the sampling distribution?
- Samples from the underlying, population–based, generative distribution
- What does this mean, exactly?
- Let's simulate to explore

Simulation

- Imagine the "real" distribution has $\mu = 100$ and $\sigma = 10$.
- Let's draw a sample of 10 from this distribution

```
set.seed(123)
samp10a <- rnorm(n = 10, mean = 100, sd = 10)
samp10a
```

```
##  [1]  94.4  97.7 115.6 100.7 101.3 117.2 104.6
##  [8]  87.3  93.1  95.5
```

- Calculate the mean

```
mean(samp10a)
```

```
## [1] 101
```

Do it a second time

```
samp10b <- rnorm(n = 10, mean = 100, sd = 10)
samp10b
```

```
##  [1] 112.2 103.6 104.0 101.1  94.4 117.9 105.0
##  [8]  80.3 107.0  95.3
```

```
mean(samp10b)
```

```
## [1] 102
```

Do it a bunch of times

```
samples <- replicate(1000, rnorm(10, mean = 100, sd = 10),
                     simplify = FALSE)
samples
```

```
## [[1]]
##  [1]  89.3  97.8  89.7  92.7  93.7  83.1 108.4
##  [8] 101.5  88.6 112.5
##
## [[2]]
##  [1] 104.3  97.0 109.0 108.8 108.2 106.9 105.5
##  [8]  99.4  96.9  96.2
##
## [[3]]
##  [1]  93.1  97.9  87.3 121.7 112.1  88.8  96.0
##  [8]  95.3 107.8  99.2
##
## [[4]]
##  [1] 102.5  99.7  99.6 113.7  97.7 115.2  84.5
##  [8] 105.8 101.2 102.2
##
## [[5]]
##  [1] 103.8  95.0  96.7  89.8  89.3 103.0 104.5
##  [8] 100.5 109.2 120.5
##
## [[6]]
```

Calculate all means

```
map_dbl(samples, mean) %>%
  head()
```

```
## [1]  95.8 103.2  99.9 102.2 101.2  96.4
```

- What's the $\boldsymbol{sd}$ of these means? That's the standard error.

```
map_dbl(samples, mean) %>%
  sd()
```

```
## [1] 3.14
```

Sample size

Let's re–do this, pulling a sample of 100 each time.

```
samples2 <- replicate(1000, rnorm(100, mean = 100, sd = 10),
                      simplify = FALSE)
map_dbl(samples2, mean) %>%
  sd()
```

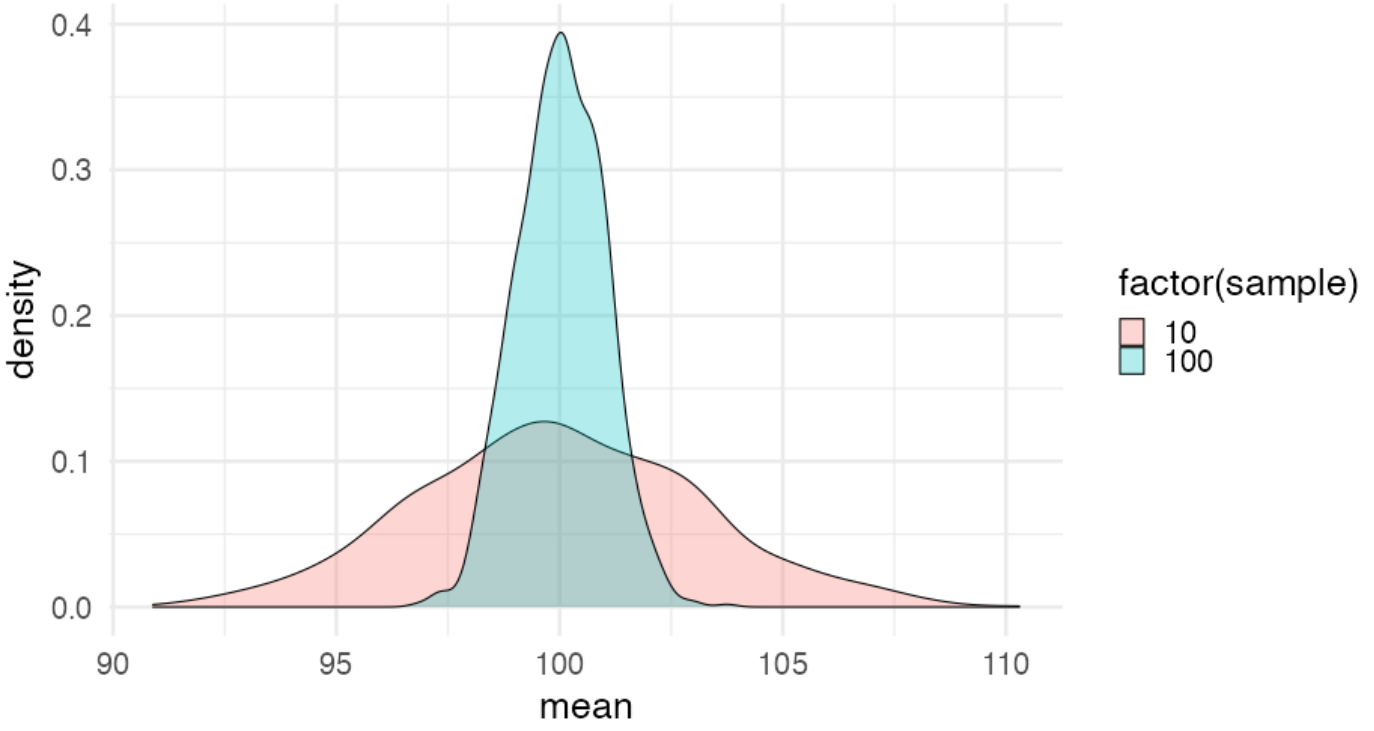
```
## [1] 0.973
```

Visualize the sampling distributions

```
sample_means <- tibble(iter = rep(1:1000, 2),
                       sample = rep(c(10, 100), each = 1000),
                       mean = c(map_dbl(samples, mean),
                                map_dbl(samples2, mean))
                       )
sample_means
```

```
## # A tibble: 2,000 × 3
##    iter sample      mean
##   <int>  <dbl>     <dbl>
## 1     1     10  95.75441
## 2     2     10 103.2204
## 3     3     10  99.91284
## 4     4     10 102.2169
## 5     5     10 101.2308
## 6     6     10  96.37082
## # … with 1,994 more rows
```

```
ggplot(sample_means, aes(mean)) +
  geom_density(aes(fill = factor(sample)), alpha = 0.3)
```



Fit a model

```
m <- lm(cty ~ displ + class, mpg)
summary(m)
```

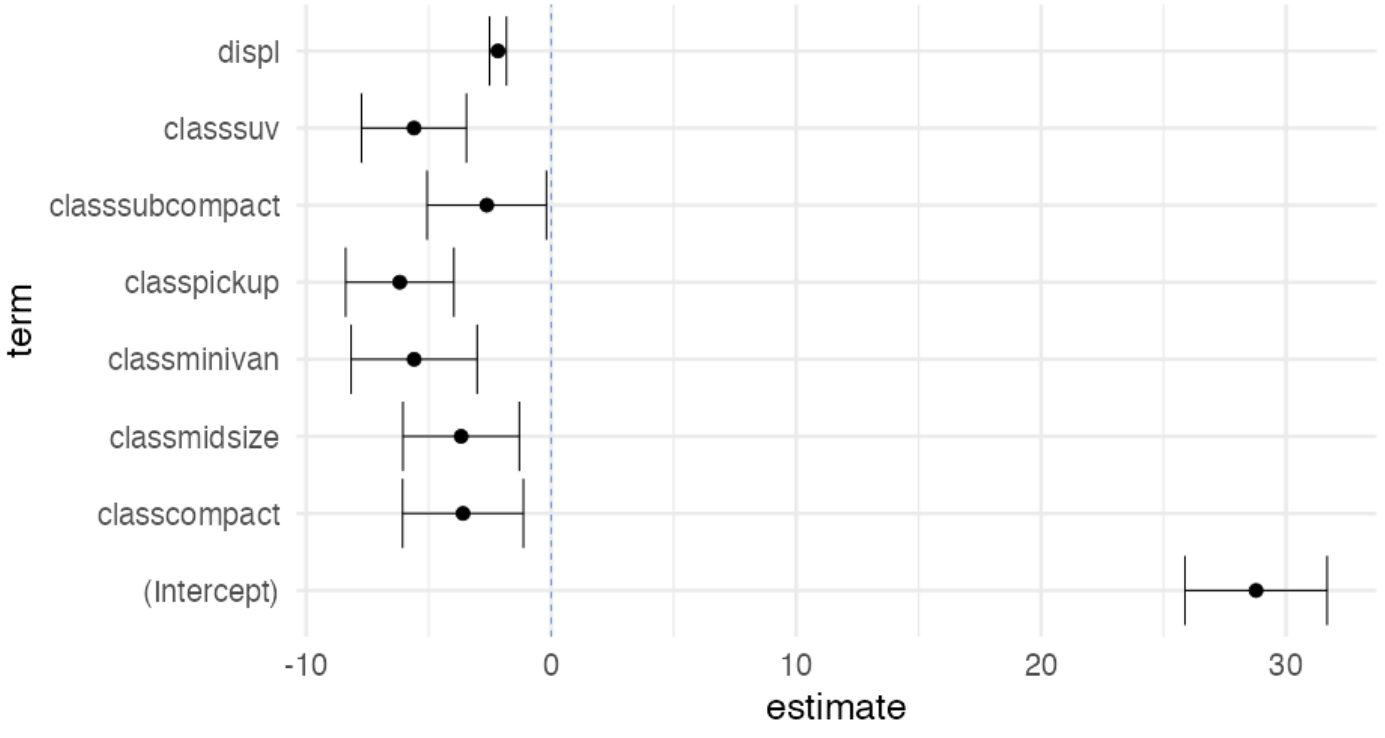
```
##
## Call:
## lm(formula = cty ~ displ + class, data = mpg)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -5.269 -1.150 -0.016  1.034 12.978
##
## Coefficients:
##                 Estimate Std. Error t value
## (Intercept)       28.777      1.473   19.54
## displ             -2.172      0.175  -12.43
## classcompact      -3.599      1.252   -2.87
## classmidsize      -3.676      1.206   -3.05
## classminivan      -5.595      1.306   -4.28
## classpickup       -6.182      1.121   -5.51
## classsubcompact   -2.629      1.237   -2.13
## classsuv          -5.599      1.087   -5.15
##                 Pr(>|t|)
## (Intercept)      < 2e-16 ***
## displ            < 2e-16 ***
## classcompact      0.0044 **
```

Visualize with standard errors

```
tidied_m <- broom::tidy(m, conf.int = TRUE)

tidied_m
```

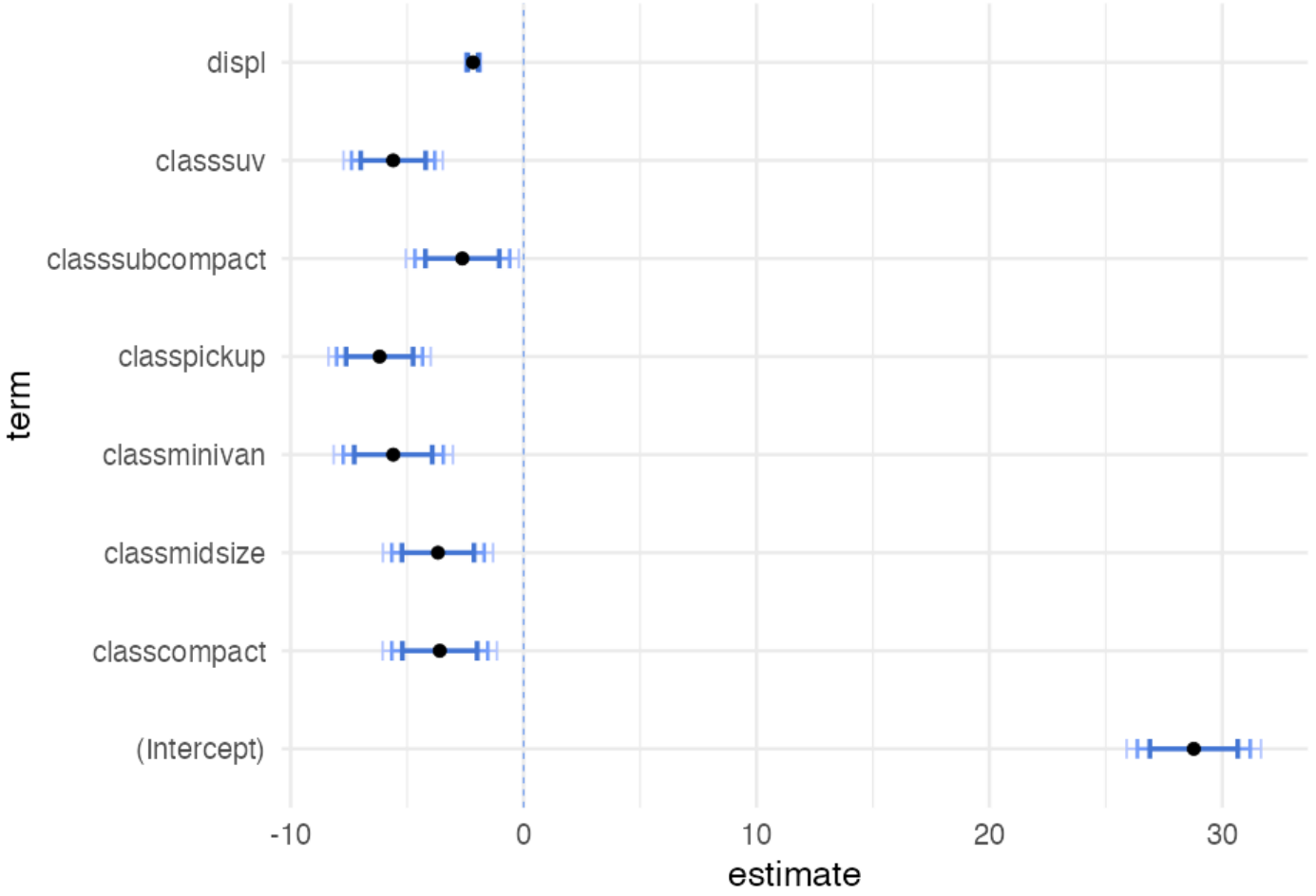
```
## # A tibble: 8 × 7
##   term          estimate std.error  statistic
##   <chr>            <dbl>     <dbl>      <dbl>
## 1 (Intercept)  28.77682  1.472892   19.53763
## 2 displ        -2.171562 0.1746638 -12.43281
## 3 classcompact -3.599125 1.252190   -2.874265
## 4 classmidsize -3.675526 1.206253   -3.047061
## 5 classminivan -5.595070 1.305993   -4.284151
## 6 classpickup  -6.182466 1.121448   -5.512931
## # … with 2 more rows, and 3 more variables:
## #   p.value <dbl>, conf.low <dbl>,
## #   conf.high <dbl>
```

```
ggplot(tidied_m, aes(term, estimate)) +
  geom_hline(yintercept = 0,
             color = "cornflowerblue",
             linetype = 2) +
  geom_errorbar(aes(ymin = conf.low, ymax = conf.high)) +
  geom_point() +
  coord_flip()
```



Multiple error bars

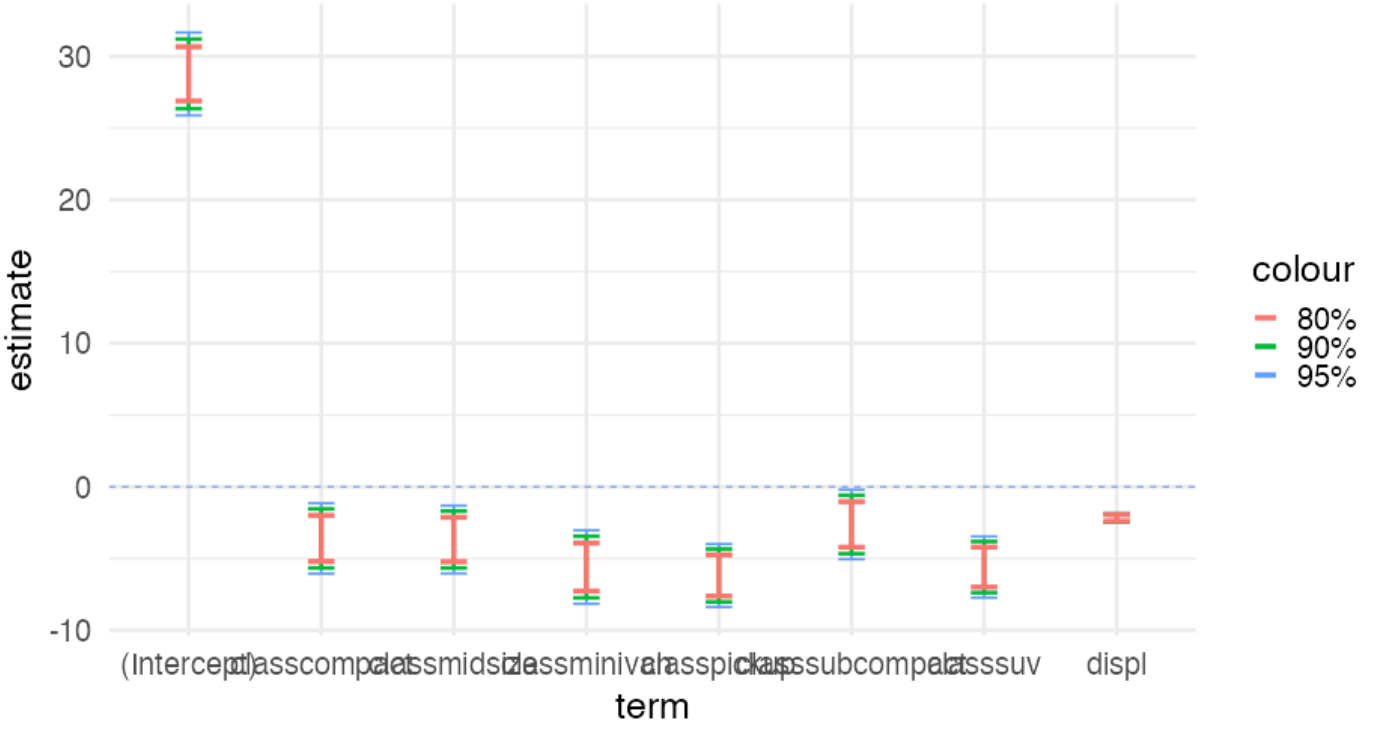
```
library(colorspace)
ggplot(tidied_m, aes(term, estimate)) +
  geom_hline(yintercept = 0,
             color = "cornflowerblue",
             linetype = 2) +
  geom_errorbar(aes(ymin = estimate + qnorm(.025)*std.error,
                    ymax = estimate + qnorm(.975)*std.error),
                color = lighten("#4375D3", .6),
                width = 0.2,
                size = 0.8) + # 95% CI
  geom_errorbar(aes(ymin = estimate + qnorm(.05)*std.error,
                    ymax = estimate + qnorm(.95)*std.error),
                color = lighten("#4375D3", .3),
                width = 0.2,
                size = 1.2) + # 90% CI
  geom_errorbar(aes(ymin = estimate + qnorm(.1)*std.error,
                    ymax = estimate + qnorm(.9)*std.error),
                color = "#4375D3",
                width = 0.2,
                size = 1.6) + # 80% CI
  geom_point() +
  coord_flip()
```


displ
classsuv
classsubcompact
classpickup
classminivan
classmidsize
classcompact
(Intercept)
term
-10
0
10
20
30
estimate

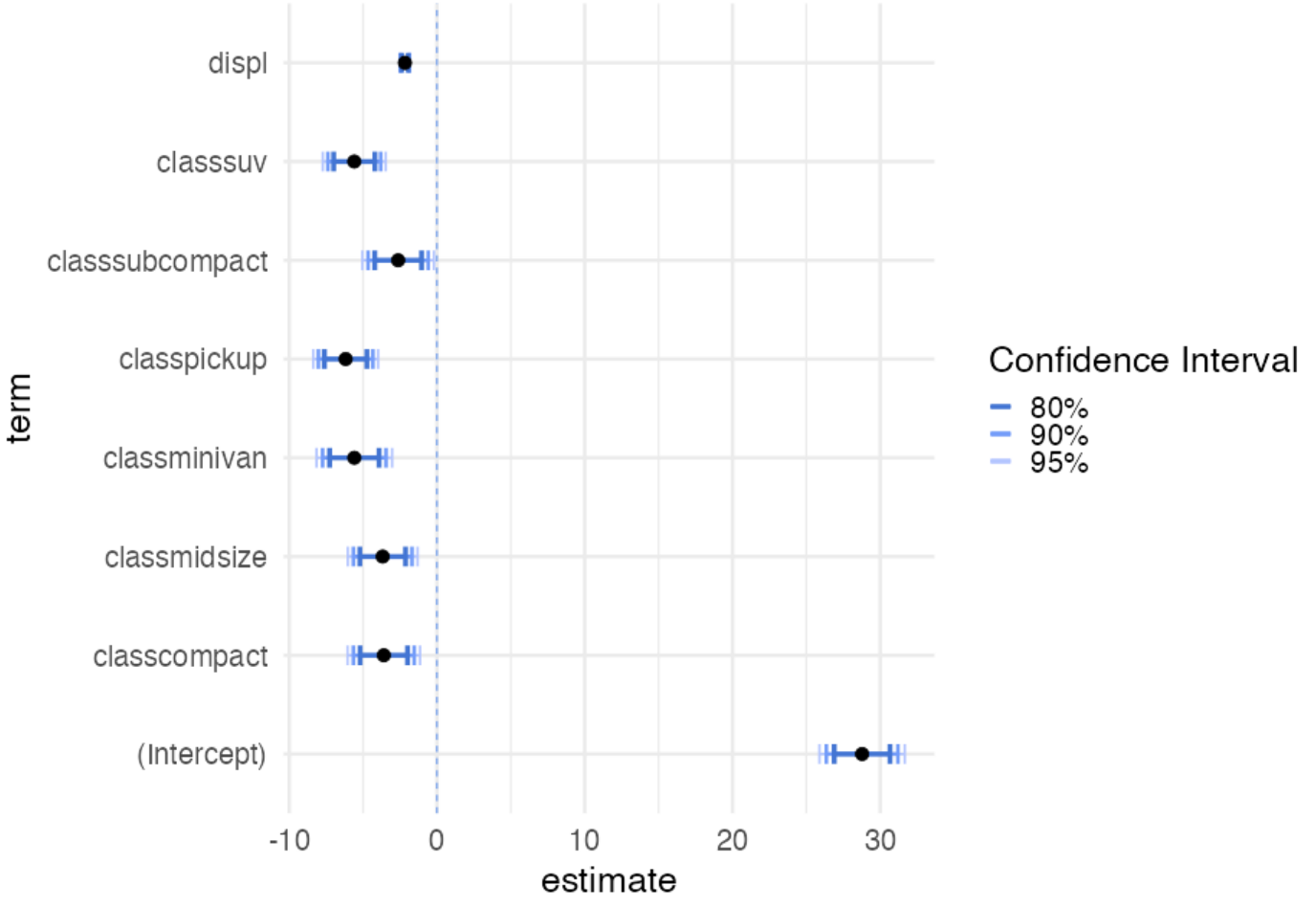
Add levels to legend

```
p <- ggplot(tidied_m, aes(term, estimate)) +
  geom_hline(yintercept = 0,
             color = "cornflowerblue",
             linetype = 2) +
  geom_errorbar(aes(ymin = estimate + qnorm(.025)*std.error,
                    ymax = estimate + qnorm(.975)*std.error,
                    color = "95%"),
                width = 0.2,
                size = 0.8) +
  geom_errorbar(aes(ymin = estimate + qnorm(.05)*std.error,
                    ymax = estimate + qnorm(.95)*std.error,
                    color = "90%"),
                width = 0.2,
                size = 1.2) +
  geom_errorbar(aes(ymin = estimate + qnorm(.1)*std.error,
                    ymax = estimate + qnorm(.9)*std.error,
                    color = "80%"),
                width = 0.2,
                size = 1.6)
```

```
p
```



```
p +
  scale_color_manual("Confidence Interval",
                     values = c("#4375D3",
                                lighten("#4375D3", .3),
                                lighten("#4375D3", .6))) +
  geom_point() +
  coord_flip()
```

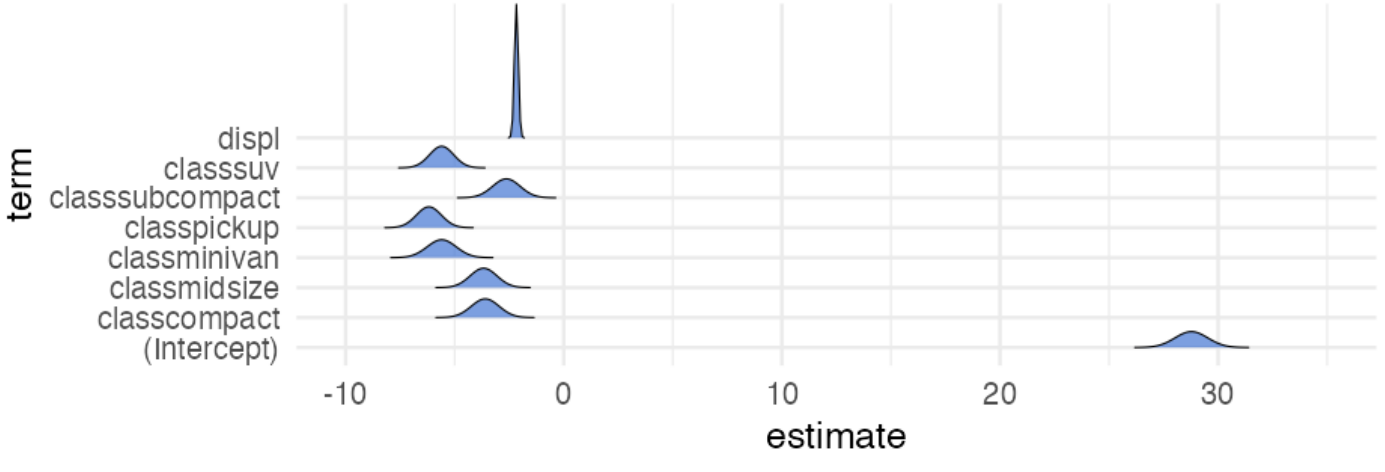

displ
classsuv
classsubcompact
classpickup
classminivan
classmidsize
classcompact
(Intercept)
term
-10
0
10
20
30
estimate
Confidence Interval
80%
90%
95%

Density stripes

```
#remotes::install_github("wilkelab/ungeviz")
library(ungeviz)
ggplot(tidied_m, aes(estimate, term)) +
  stat_confidence_density(
    aes(moe = std.error),
    fill = "#4375D3",
    height = 0.6
  ) +
  xlim(-10, 35) +
  geom_point()
```

Actual densities

```
library(ggridges)
ggplot(tidied_m, aes(estimate, term)) +
  stat_confidence_density(
    aes(moe = std.error, height = stat(density)),
    geom = "ridgeline",
    confidence = 0.95,
    min_height = 0.001,
    alpha = 0.7,
    fill = "#4375D3"
  ) +
  xlim(-10, 35)
```



Practice

- Go back to your species means from Palmer Penguins
- Reproduce the plot using one of the three methods we just saw
    - Multiple error bars
    - Density stripes
    - Densities

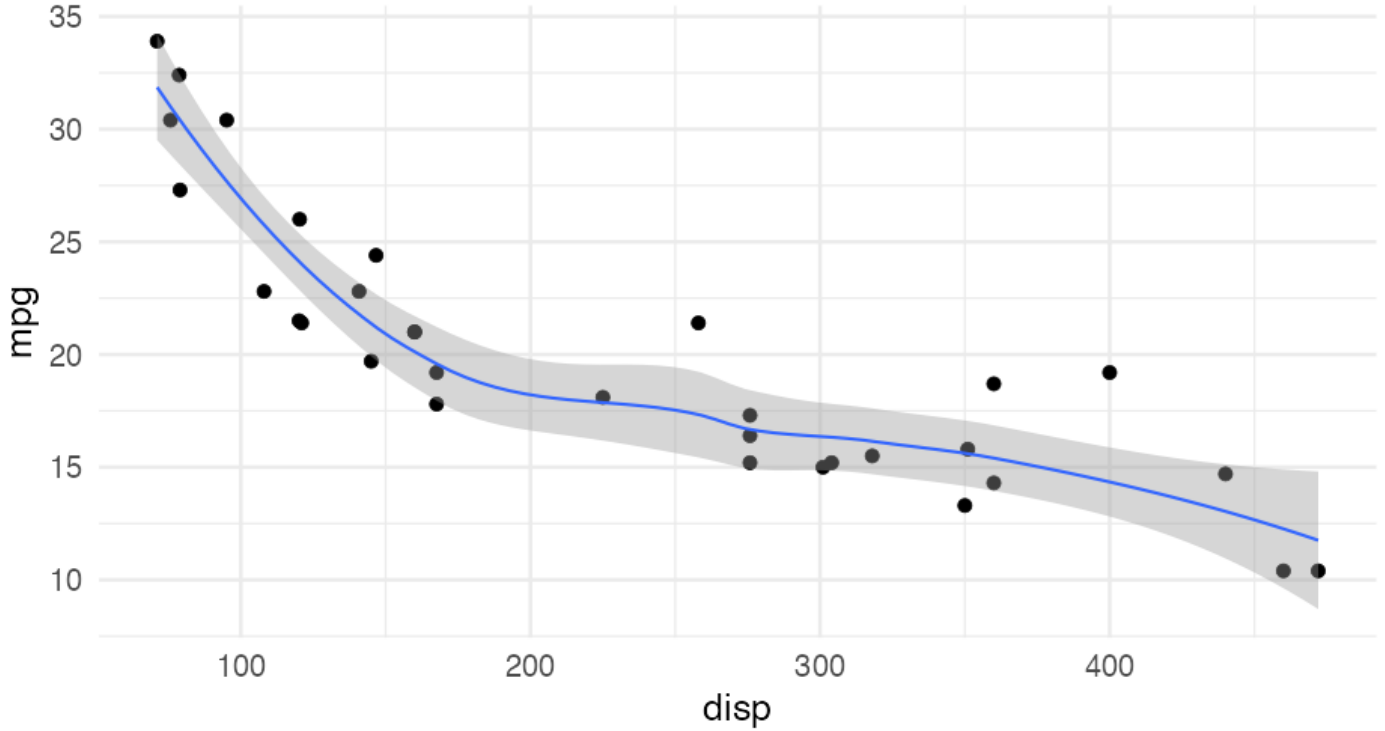
05:00

HOPs

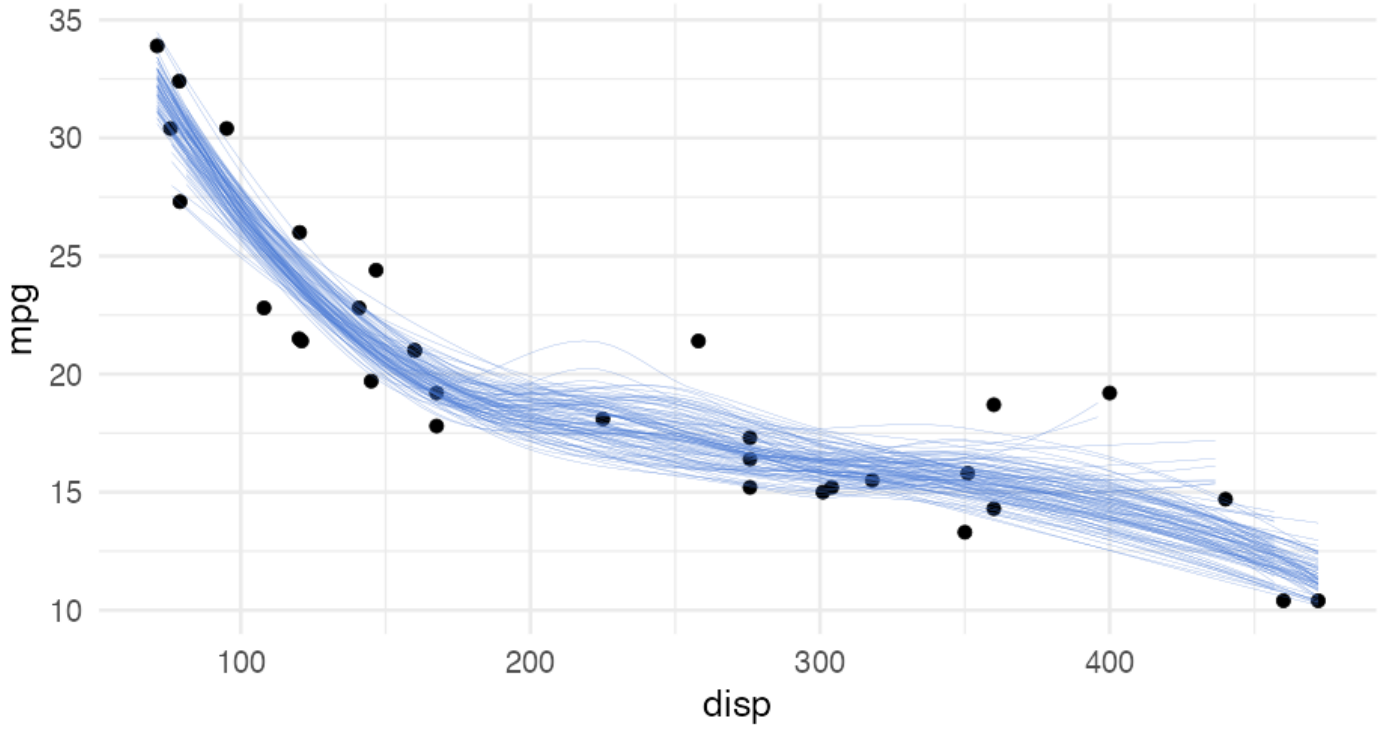
Hypothetical Outcome Plots (and related plots)

Standard regression plot

```
ggplot(mtcars, aes(disp, mpg)) +
  geom_point() +
  geom_smooth()
```



Alternative



How?

Bootstrapping

```
row_samps <- replicate(
  100,
  sample(
    seq_len(nrow(mtcars)),
    nrow(mtcars),
    replace = TRUE
  ),
  simplify = FALSE
)

row_samps
```

```
## [[1]]
##  [1] 22 30 25 25  5 31 19 13 19 20 17  1  4 12 12
## [16] 25 20 21 16 23 11 23 14  1 24 20 10 30 27 24
## [31] 22 23
##
## [[2]]
##  [1] 25  1 18 18 25  8  8 16 25 19 31 13 11 10 21
## [16]  6 14 14 12 24 27 29 22  5  6  8 14 16  7 13
## [31] 17 13
```

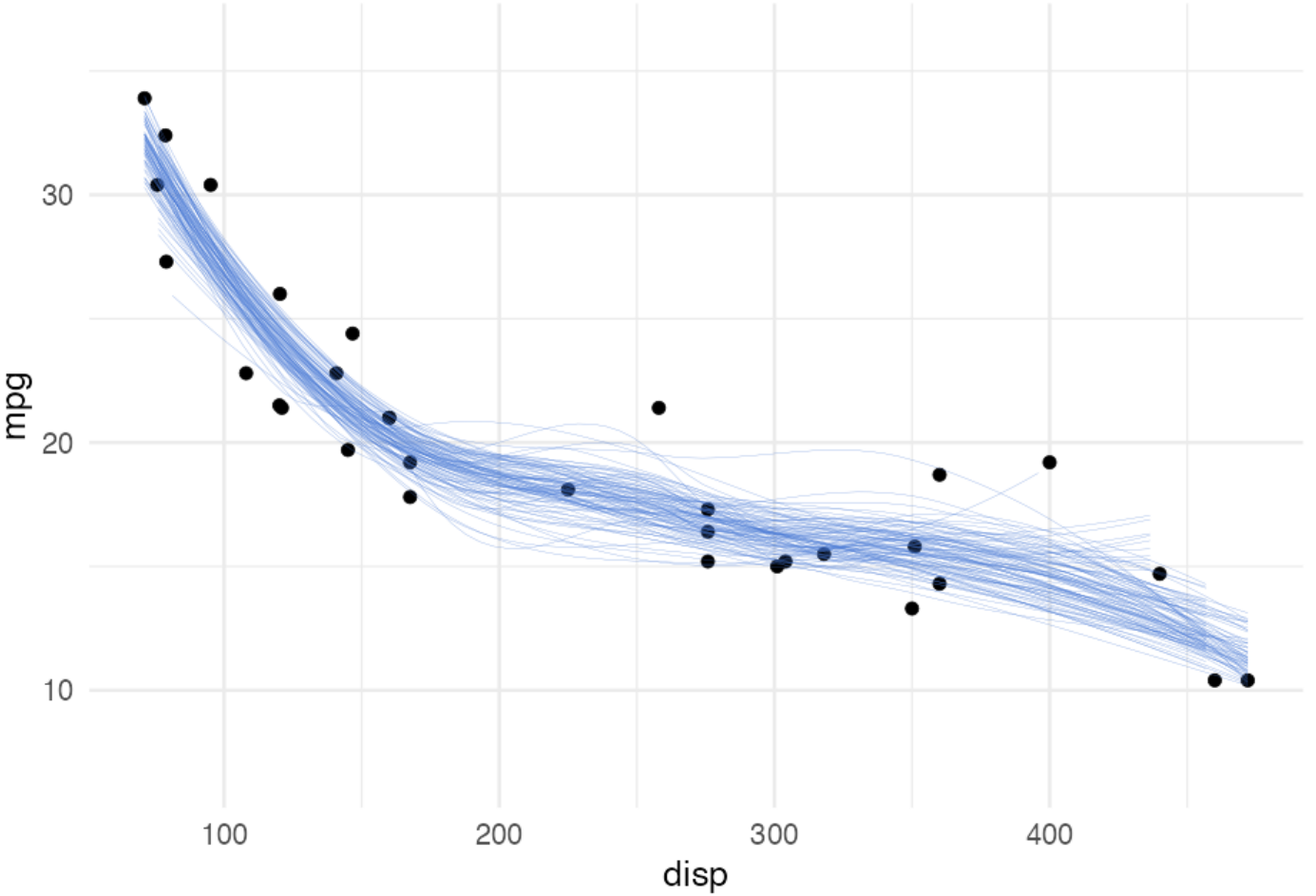
Extract samples

```
d_samps <- map_df(row_samps, ~mtcars[.x, ], .id = "sample")
head(d_samps)
```

```
##                        sample  mpg cyl disp  hp
## Dodge Challenger...1        1 15.5   8  318 150
## Ferrari Dino...2            1 19.7   6  145 175
## Pontiac Firebird...3        1 19.2   8  400 175
## Pontiac Firebird.1...4      1 19.2   8  400 175
## Hornet Sportabout...5       1 18.7   8  360 175
## Maserati Bora...6           1 15.0   8  301 335
##                        drat   wt qsec vs am gear
## Dodge Challenger...1   2.76 3.52 16.9  0  0    3
## Ferrari Dino...2       3.62 2.77 15.5  0  1    5
## Pontiac Firebird...3   3.08 3.85 17.1  0  0    3
## Pontiac Firebird.1...4 3.08 3.85 17.1  0  0    3
## Hornet Sportabout...5  3.15 3.44 17.0  0  0    3
## Maserati Bora...6      3.54 3.57 14.6  0  1    5
##                        carb
## Dodge Challenger...1      2
## Ferrari Dino...2          6
## Pontiac Firebird...3      2
## Pontiac Firebird.1...4    2
## Hornet Sportabout...5     2
## Maserati Bora...6         8
```

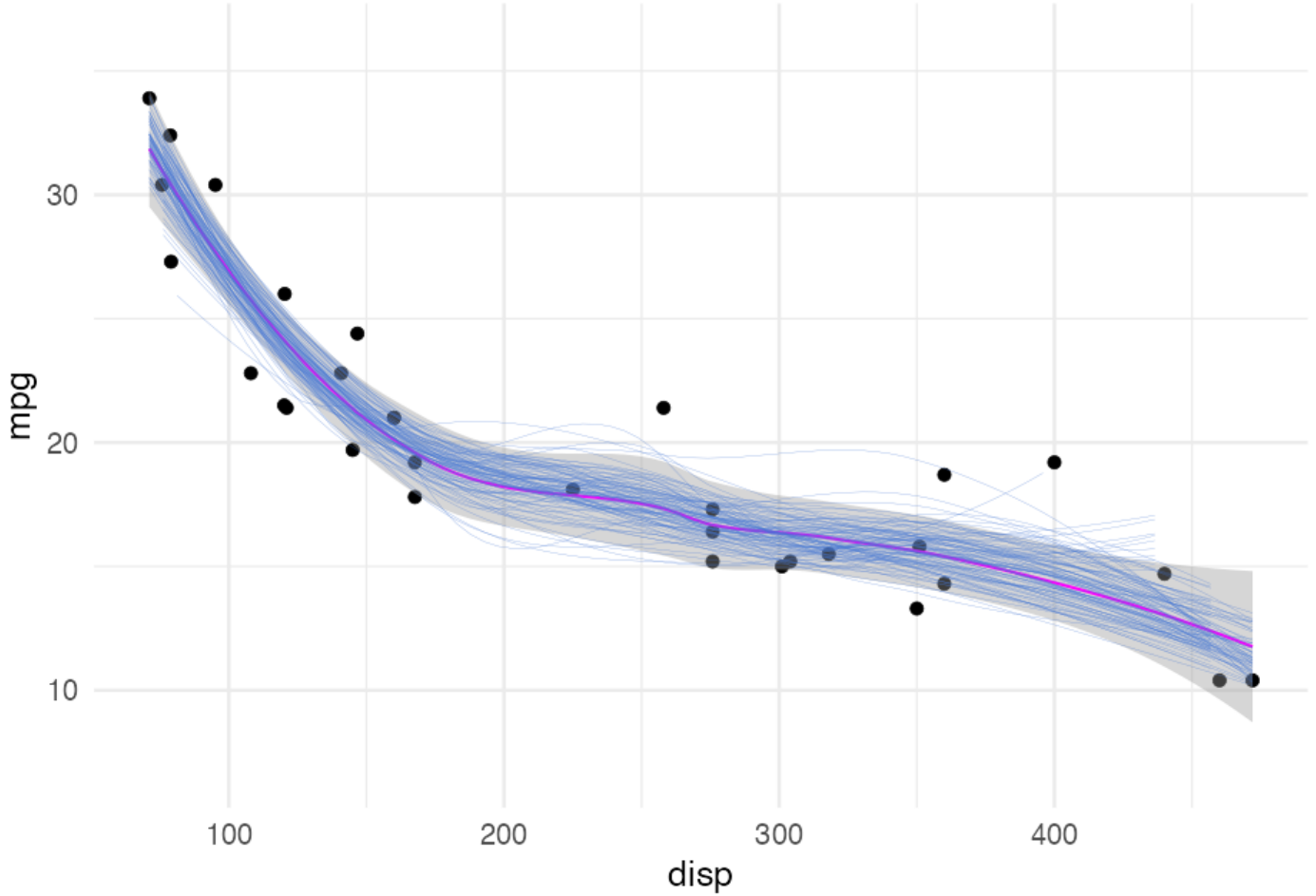
Plot both data sources

```
ggplot(mtcars, aes(disp, mpg)) +
  geom_point() +
  stat_smooth(
    aes(group = sample),
    data = d_samps,
    geom = "line",
    color = "#4375D3",
    fullrange = TRUE,
    size = 0.1
  )
```


30
20
10
mpg
100
200
300
400
disp

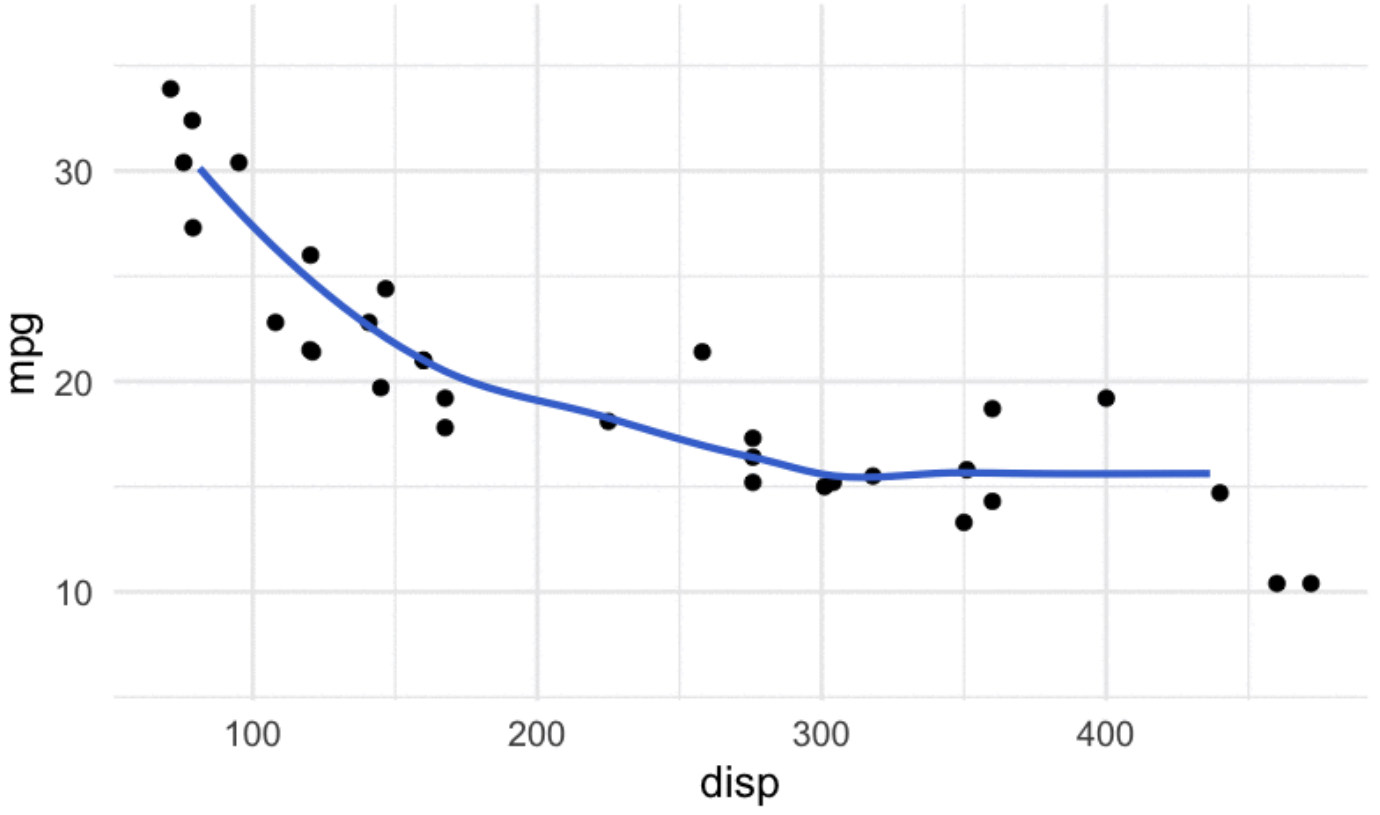
Note, they match up

```
ggplot(mtcars, aes(disp, mpg)) +
  geom_point() +
  geom_smooth(color = "magenta") +
  stat_smooth(
    aes(group = sample),
    data = d_samps,
    geom = "line",
    color = "#4375D3",
    fullrange = TRUE,
    size = 0.1
  )
```


30
20
10
mpg
100
200
300
400
disp

HOPs

Hops animate the process, so you can't settle on one "truth"

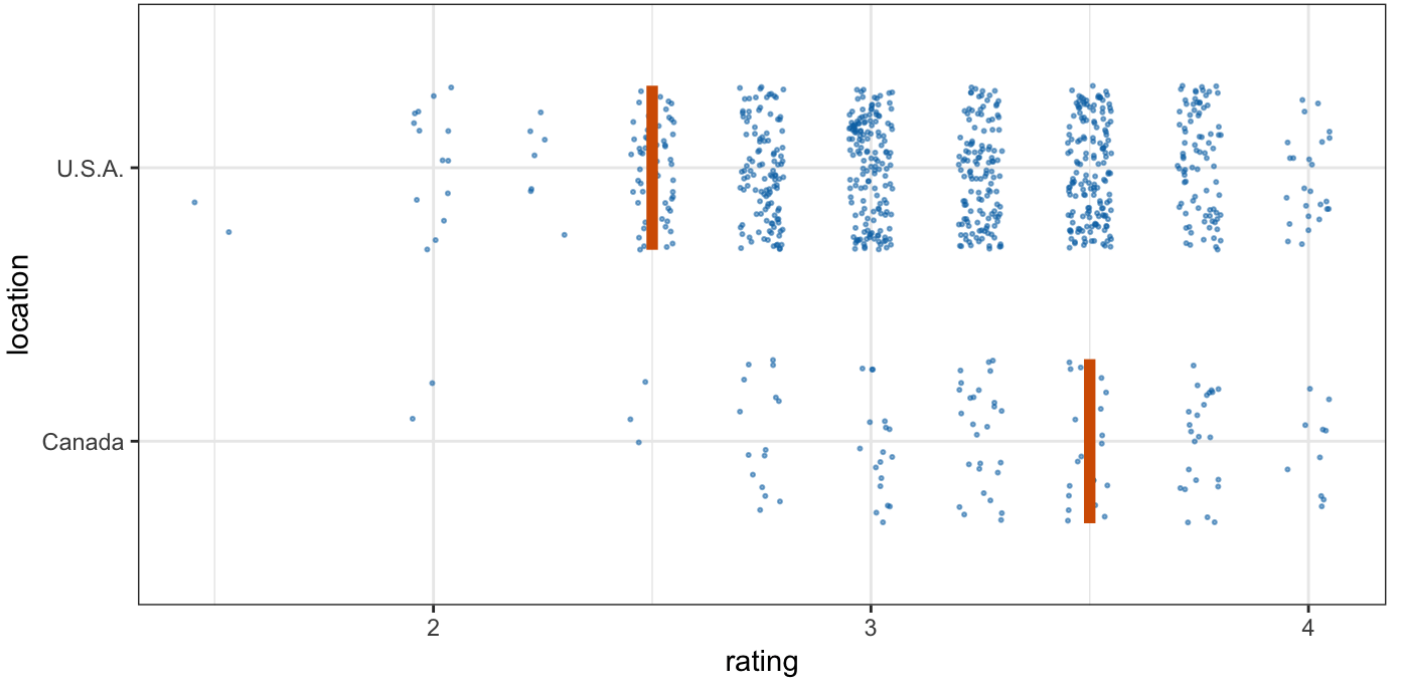


How?

gganimate::transition_states

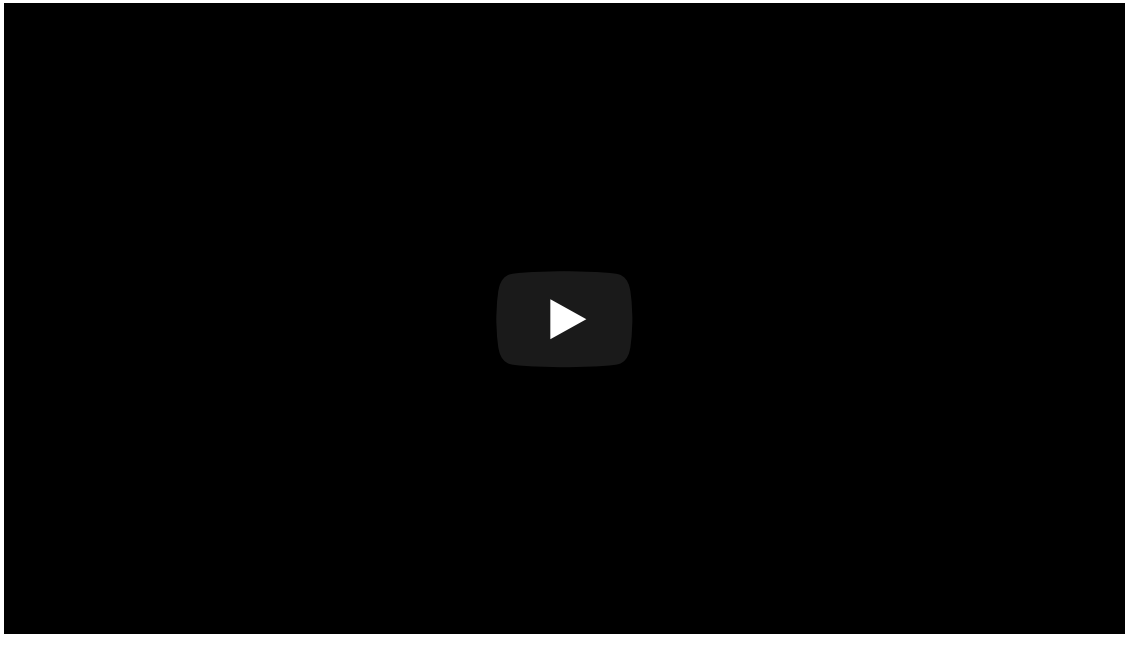
```
library(gganimate)
ggplot(mtcars, aes(disp, mpg)) +
  geom_point() +
  stat_smooth(
    data = d_samps,
    geom = "line",
    size = 2,
    color = "#4375D3",
    fullrange = TRUE
  ) +
  transition_states(
    sample,
    transition_length = 0.5,
    state_length = 0.5
  ) +
  ease_aes('linear') # Smoother transitions
```

Another example



Another examples

From Dr. Kay again



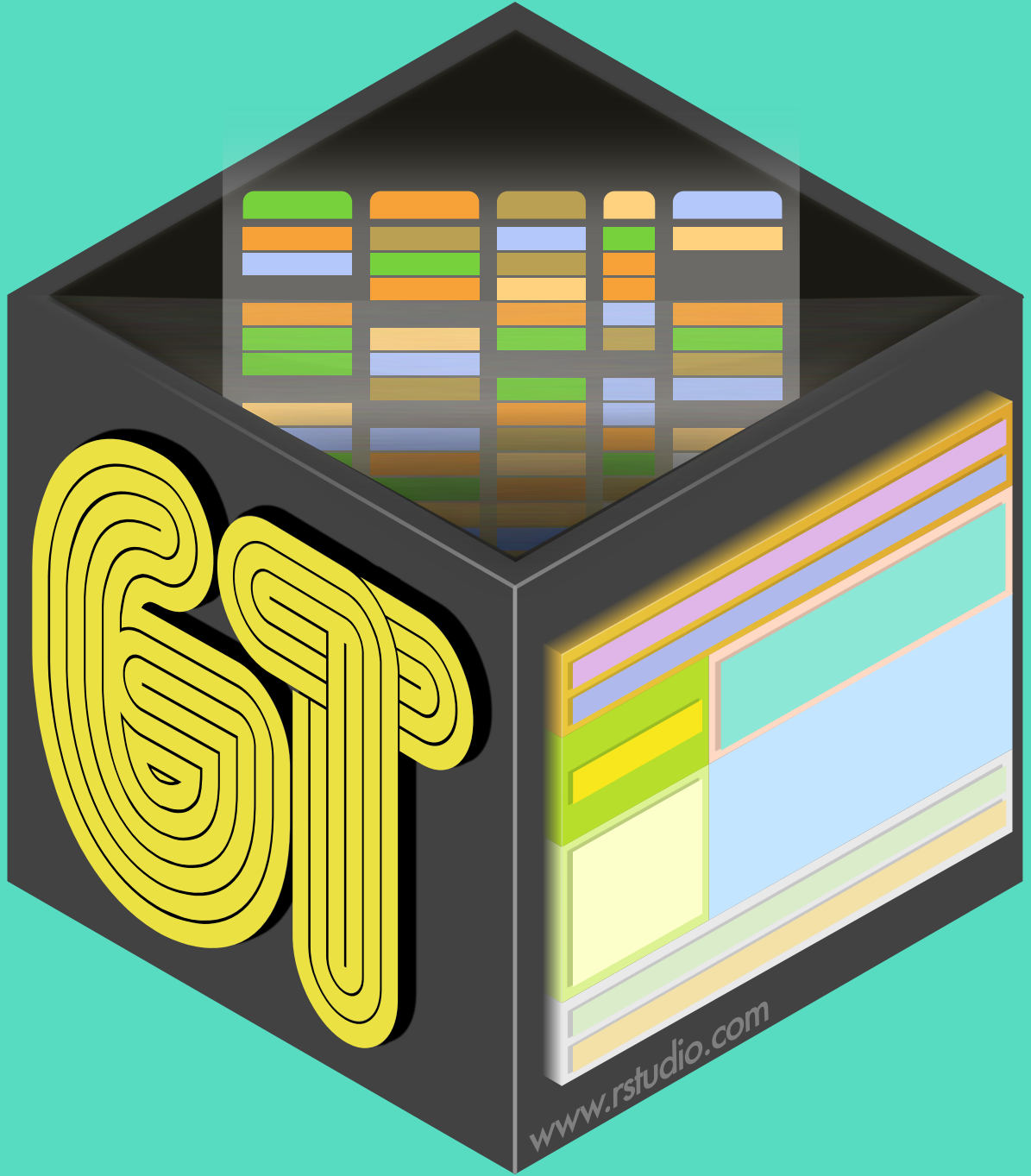
Conclusions

- Lots of tools at your disposal (perhaps so many it can be difficult to choose)
- Do try to communicate uncertainty whenever possible
- I'd recommend checking out Clause Wilke's talk from `rstudio::conf(2019L)`, where he talks about the ungeviz package.

Break

05:00

Tables


www.rstudio.com

Overview

- Pipe–oriented
- Beautiful tables easy
- Spanner heads/grouping used to be a total pain – not so anymore
- Renders to HTML/PDF without even thinking about it

Probably my favorite package for creating static tables, although **kableExtra** is great too.

My experience is that fewer people are generally familiar with **gt**, which is why I cover it here.

Install

```
install.packages("gt")

# or

remotes::install_github("rstudio/gt")
```

Please follow along

01:00

The hard part

- Getting your data in the format you want a table in
- Utilize your `pivot_*` skills regularly

```
library(fivethirtyeight)
flying
```

```
## # A tibble: 1,040 × 27
##   respondent_id gender age   height
##           <dbl> <chr>  <ord> <ord>
## 1    3436139758 <NA>   <NA>   <NA>
## 2    3434278696 Male   30-44 "6'3\""
## 3    3434275578 Male   30-44 "5'8\""
## 4    3434268208 Male   30-44 "5'11\""
## 5    3434250245 Male   30-44 "5'7\""
## 6    3434245875 Male   30-44 "5'9\""
## # … with 1,034 more rows, and 23 more variables:
## #   children_under_18 <lgl>,
## #   household_income <ord>, education <ord>,
## #   location <chr>, frequency <ord>,
## #   recline_frequency <ord>,
## #   recline_obligation <lgl>, recline_rude <ord>,
## #   recline_eliminate <lgl>, …
```

```
flying %>%
  count(gender, age, recline_frequency)
```

```
## # A tibble: 53 × 4
##   gender age   recline_frequency       n
##   <chr>  <ord> <ord>               <int>
## 1 Female 18-29 Never                  24
## 2 Female 18-29 Once in a while        36
## 3 Female 18-29 About half the time    10
## 4 Female 18-29 Usually                13
## 5 Female 18-29 Always                 10
## 6 Female 18-29 <NA>                   19
## # … with 47 more rows
```

```
smry <- flying %>%
  count(gender, age, recline_frequency) %>%
  drop_na(age,recline_frequency) %>%
  pivot_wider(names_from = "age",
              values_from = "n")
smry
```

```
## # A tibble: 10 × 6
##   gender recline_frequency   `18-29` `30-44`
##   <chr>  <ord>                 <int>   <int>
## 1 Female Never                    24      21
## 2 Female Once in a while          36      25
## 3 Female About half the time      10      22
## 4 Female Usually                  13      22
## 5 Female Always                   10      21
## 6 Male   Never                    24      17
## # … with 4 more rows, and 2 more variables:
## #   `45-60` <int>, `> 60` <int>
```

Turn into table

```
library(gt)
smry %>%
  gt()
```

Disclaimer: these all look slightly different on the slides

The way they look for you locally is how they will render in standard R Markdown files

gender	recline_frequency	18–29	30–44	45–60	> 60
Female	Never	24	21	19	23
Female	Once in a while	36	25	30	36
Female	About half the time	10	22	18	17
Female	Usually	13	22	26	28
Female	Always	10	21	29	12
Male	Never	24	17	20	18
Male	Once in a while	19	39	40	29
Male	About half the time	11	11	16	11
Male	Usually	14	30	15	27
Male	Always	11	14	21	14

Add gender as a grouping variable

```
smry %>%
  group_by(gender) %>%
  gt()
```

recline_frequency	18–29	30–44	45–60	> 60
Female				
Never	24	21	19	23
Once in a while	36	25	30	36
About half the time	10	22	18	17
Usually	13	22	26	28
Always	10	21	29	12
Male				
Never	24	17	20	18
Once in a while	19	39	40	29
About half the time	11	11	16	11
Usually	14	30	15	27
Always	11	14	21	14

This is an example of a table that looks better with the default CSS

Add a spanner head

```
smry %>%
  group_by(gender) %>%
  gt() %>%
  tab_spanner(
    label = "Age Range",
    columns = vars(`18-29`, `30-44`, `45-60`, `> 60`)
  )
```

	Age Range			
recline_frequency	18–29	30–44	45–60	> 60
Female				
Never	24	21	19	23
Once in a while	36	25	30	36
About half the time	10	22	18	17
Usually	13	22	26	28
Always	10	21	29	12
Male				
Never	24	17	20	18
Once in a while	19	39	40	29
About half the time	11	11	16	11
Usually	14	30	15	27
Always	11	14	21	14

Change column names

```
smry %>%
  group_by(gender) %>%
  gt() %>%
  tab_spanner(
    label = "Age Range",
    columns = vars(`18-29`, `30-44`, `45-60`, `> 60`)
  ) %>%
  cols_label(recline_frequency = "Recline")
```

	Age Range			
Recline	18–29	30–44	45–60	> 60
Female				
Never	24	21	19	23
Once in a while	36	25	30	36
About half the time	10	22	18	17
Usually	13	22	26	28
Always	10	21	29	12
Male				
Never	24	17	20	18
Once in a while	19	39	40	29
About half the time	11	11	16	11
Usually	14	30	15	27
Always	11	14	21	14

Align columns

```
smry %>%
  group_by(gender) %>%
  gt() %>%
  tab_spanner(
    label = "Age Range",
    columns = vars(`18-29`, `30-44`, `45-60`, `> 60`)
  ) %>%
  cols_label(recline_frequency = "Recline") %>%
  cols_align(align = "left",
             columns = vars(recline_frequency))
```

	Age Range			
Recline	18–29	30–44	45–60	> 60
Female				
Never	24	21	19	23
Once in a while	36	25	30	36
About half the time	10	22	18	17
Usually	13	22	26	28
Always	10	21	29	12
Male				
Never	24	17	20	18
Once in a while	19	39	40	29
About half the time	11	11	16	11
Usually	14	30	15	27
Always	11	14	21	14

Add a title

```
smry %>%
  group_by(gender) %>%
  gt() %>%
  tab_spanner(
    label = "Age Range",
    columns = vars(`18-29`, `30-44`, `45-60`, `> 60`)
  ) %>%
  cols_label(recline_frequency = "Recline") %>%
  cols_align(align = "left",
             columns = vars(recline_frequency)) %>%
  tab_header(
    title = "Airline Passengers",
    subtitle = "Leg space is limited, what do you do?"
  )
```

Airline Passengers

Leg space is limited, what do you do?

	Age Range			
Recline	18–29	30–44	45–60	> 60
Female				
Never	24	21	19	23
Once in a while	36	25	30	36
About half the time	10	22	18	17
Usually	13	22	26	28
Always	10	21	29	12
Male				
Never	24	17	20	18
Once in a while	19	39	40	29
About half the time	11	11	16	11
Usually	14	30	15	27
Always	11	14	21	14

Format columns

```
smry %>%
  mutate(across(c(`18-29`, `30-44`, `45-60`, `> 60`),
                ~.x/100)) %>%
  group_by(gender) %>%
  gt() %>%
  tab_spanner(
    label = "Age Range",
    columns = vars(`18-29`, `30-44`, `45-60`, `> 60`)
  ) %>%
  fmt_percent(
    vars(`18-29`, `30-44`, `45-60`, `> 60`),
    decimals = 0
  ) %>%
  cols_label(recline_frequency = "Recline") %>%
  cols_align(align = "left",
             columns = vars(recline_frequency)) %>%
  tab_header(
    title = "Airline Passengers",
    subtitle = "Leg space is limited, what do you do?"
  )
```

Airline Passengers

Leg space is limited, what do you do?

	Age Range			
Recline	18–29	30–44	45–60	> 60
Female				
Never	24%	21%	19%	23%
Once in a while	36%	25%	30%	36%
About half the time	10%	22%	18%	17%
Usually	13%	22%	26%	28%
Always	10%	21%	29%	12%
Male				
Never	24%	17%	20%	18%
Once in a while	19%	39%	40%	29%
About half the time	11%	11%	16%	11%
Usually	14%	30%	15%	27%
Always	11%	14%	21%	14%

Add a source note

```
smry %>%
  mutate(across(c(`18-29`, `30-44`, `45-60`, `> 60`),
                ~.x/100)) %>%
  group_by(gender) %>%
  gt() %>%
  tab_spanner(
    label = "Age Range",
    columns = vars(`18-29`, `30-44`, `45-60`, `> 60`)
  ) %>%
  fmt_percent(
    vars(`18-29`, `30-44`, `45-60`, `> 60`),
    decimals = 0
  ) %>%
  cols_label(recline_frequency = "Recline") %>%
  cols_align(align = "left",
             columns = vars(recline_frequency)) %>%
  tab_header(
    title = "Airline Passengers",
    subtitle = "Leg space is limited, what do you do?"
  ) %>%
  tab_source_note(
    source_note = md("Data from [fivethirtyeight](https://fiveth
  )
```

Airline Passengers

Leg space is limited, what do you do?

	Age Range			
Recline	18–29	30–44	45–60	> 60
Female				
Never	24%	21%	19%	23%
Once in a while	36%	25%	30%	36%
About half the time	10%	22%	18%	17%
Usually	13%	22%	26%	28%
Always	10%	21%	29%	12%
Male				
Never	24%	17%	20%	18%
Once in a while	19%	39%	40%	29%
About half the time	11%	11%	16%	11%
Usually	14%	30%	15%	27%
Always	11%	14%	21%	14%

Data from fivethirtyeight

Color cells

```
... %>%
  data_color(
    vars(`18-29`, `30-44`, `45-60`, `> 60`),
    colors = scales::col_numeric(
      palette = c("#FFFFFF", "#FF0000"),
      domain = NULL
    )
  ) %>%
  ...
```

Airline Passengers

Leg space is limited, what do you do?

	Age Range			
Recline	18–29	30–44	45–60	> 60
Female				
Never	24%	21%	19%	23%
Once in a while	36%	25%	30%	36%
About half the time	10%	22%	18%	17%
Usually	13%	22%	26%	28%
Always	10%	21%	29%	12%
Male				
Never	24%	17%	20%	18%
Once in a while	19%	39%	40%	29%
About half the time	11%	11%	16%	11%
Usually	14%	30%	15%	27%
Always	11%	14%	21%	14%

Data from fivethirtyeight

What else?

- Lots more it can do, and lots more in development
- See the website

Thomas Mock does a lot of great work with tables and often has tutorials showing your how to go further (e.g., see here and here and here).

A few other table options

kableExtra

A few quick examples

Make sure to specify `results = "asis"` in your chunk options.

```
library(knitr)
library(kableExtra)
dt <- mtcars[1:5, 1:6]
kable(dt) %>%
  kable_styling("striped") %>%
  column_spec(5:7, bold = TRUE
```

	mpg	cyl	disp	hp	drat	wt
Mazda RX4	21.0	6	160	**110**	**3.90**	**2.62**
Mazda RX4 Wag	21.0	6	160	**110**	**3.90**	**2.88**
Datsun 710	22.8	4	108	**93**	**3.85**	**2.32**
Hornet 4 Drive	21.4	6	258	**110**	**3.08**	**3.21**
Hornet Sportabout	18.7	8	360	**175**	**3.15**	**3.44**

```
kable(dt) %>%
  kable_styling("striped") %>%
  column_spec(5:7, bold = TRUE) %>%
  row_spec(c(2, 4),
           bold = TRUE,
           color = "#EFF3F7",
           background = "#71B0DE")
```

	mpg	cyl	disp	hp	drat	wt
Mazda RX4	21.0	6	160	**110**	**3.90**	**2.62**
Mazda RX4 Wag	**21.0**	**6**	**160**	**110**	**3.90**	**2.88**
Datsun 710	22.8	4	108	**93**	**3.85**	**2.32**
Hornet 4 Drive	**21.4**	**6**	**258**	**110**	**3.08**	**3.21**
Hornet Sportabout	18.7	8	360	**175**	**3.15**	**3.44**

```
kable(dt) %>%
  kable_styling("striped", full_width = FALSE) %>%
  pack_rows(
    "Group 1", 1, 3,
    label_row_css = "background-color: #666; color: #fff;"
  ) %>%
  pack_rows(
    "Group 2", 4, 5,
    label_row_css = "background-color: #666; color: #fff;"
  )
```

	mpg	cyl	disp	hp	drat	wt
Group 1						
Mazda RX4	21.0	6	160	110	3.90	2.62
Mazda RX4 Wag	21.0	6	160	110	3.90	2.88
Datsun 710	22.8	4	108	93	3.85	2.32
Group 2						
Hornet 4 Drive	21.4	6	258	110	3.08	3.21
Hornet Sportabout	18.7	8	360	175	3.15	3.44

KableExtra wrapup

Many other options, please see the documentation. Works well for PDF and HTML.

What about Microsoft Word?

flextable

flextable R package

The flextable package provides a framework for easily create tables for reporting and publications. Tables can be embedded within:

- R Markdown documents with support for HTML, Word and PowerPoint documents.
- Microsoft Word or PowerPoint documents.
- PDF documents with package `pagedown` (it's only HTML)

Tables can also be rendered as R plots or graphic files (png, pdf and jpeg).

Getting Started

An API is available to let R users create tables for reporting and control their formatting properties and their layout. A `flextable` object is a data.frame representation, it can be manipulated with functions that give control over:

Links

Download from CRAN at
https://cloud.r-project.org/package=flextable

Report a bug at
https://github.com/davidgohel/flextable/issues

Visit ARDATA website at
https://www.ardata.fr

License

GPL-3

Developers

David Gohel
Author, maintainer

All authors...

Many others

- huxtable
- formattable
- DT (my former favorite for shiny)
- rhandsontable

Particularly helpful for modeling

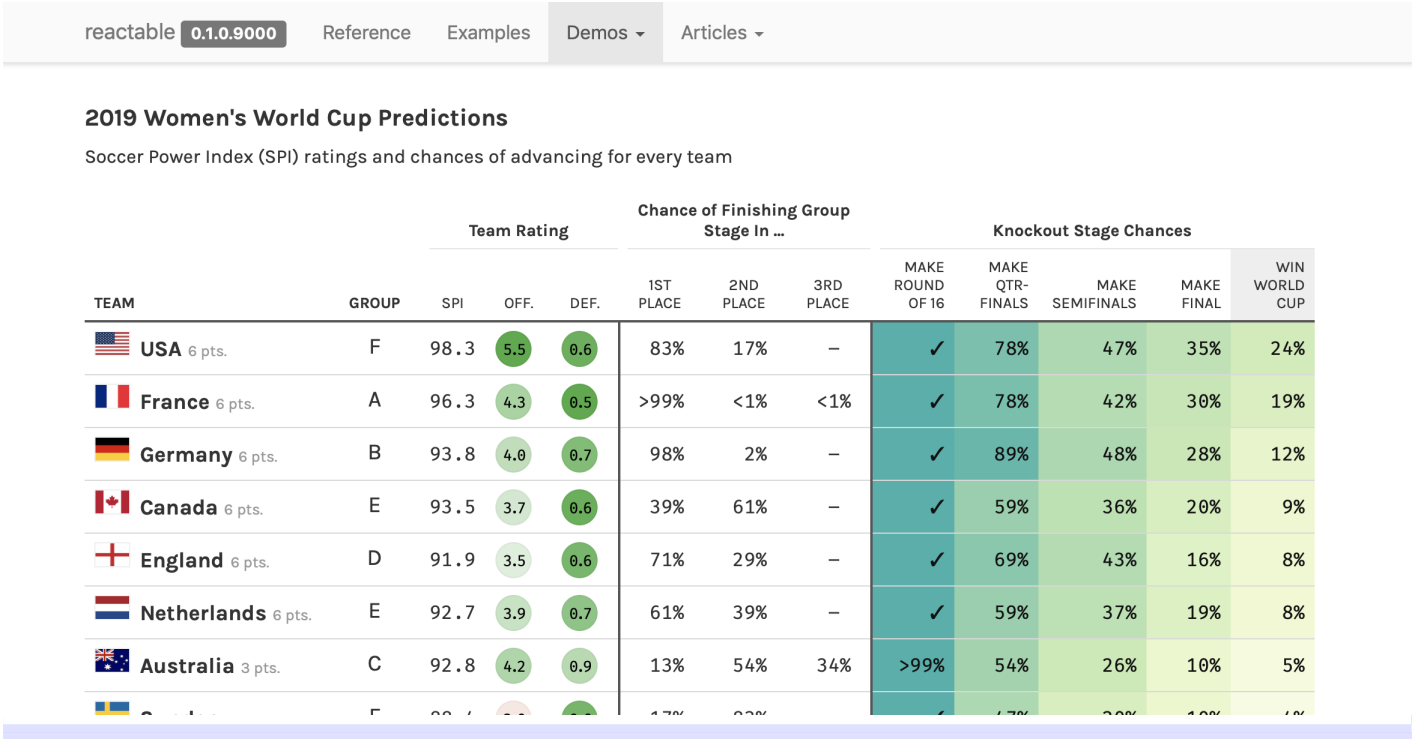
- stargazer
- pixiedust
- modelsummary

For descriptives

- gtsummary

reactable

My favorite for interactive tables



Works great with **shiny** too

Penguins data

```
library(reactable)
reactable(penguins)
```

species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g	sex
Adelie	Torgersen	39.1	18.7	181	3750	male
Adelie	Torgersen	39.5	17.4	186	3800	female
Adelie	Torgersen	40.3	18	195	3250	female
Adelie	Torgersen					
Adelie	Torgersen	36.7	19.3	193	3450	female
Adelie	Torgersen	39.3	20.6	190	3650	male
Adelie	Torgersen	38.9	17.8	181	3625	female
Adelie	Torgersen	39.2	19.6	195	4675	male
Adelie	Torgersen	34.1	18.1	193	3475	
Adelie	Torgersen	42	20.2	190	4250	

1–10 of 344 rows

Previous 1 2 3 4 5 ... 35 Next

Rename columns

```
penguins %>%
  reactable(
    columns = list(
      bill_length_mm = colDef(name = "Bill Length (mm)"),
      bill_depth_mm = colDef(name = "Bill Depth (mm)")
    )
  )
```

species	island	Bill Length (mm)	Bill Depth (mm)	flipper_length_mm	body_mass_g	sex
Adelie	Torgersen	39.1	18.7	181	3750	male
Adelie	Torgersen	39.5	17.4	186	3800	female
Adelie	Torgersen	40.3	18	195	3250	female
Adelie	Torgersen					
Adelie	Torgersen	36.7	19.3	193	3450	female
Adelie	Torgersen	39.3	20.6	190	3650	male
Adelie	Torgersen	38.9	17.8	181	3625	female
Adelie	Torgersen	39.2	19.6	195	4675	male
Adelie	Torgersen	34.1	18.1	193	3475	
Adelie	Torgersen	42	20.2	190	4250	

1—10 of 344 rows

Previous 1 2 3 4 5 ... 35 Next

Or use a function

```
library(stringr)

penguins %>%
  reactable(
    defaultColDef = colDef(
      header = function(x) str_to_title(gsub("_", " ", x))
    )
  )
```

Species	Island	Bill Length Mm	Bill Depth Mm	Flipper Length Mm	Body Mass G	Sex
Adelie	Torgersen	39.1	18.7	181	3750	male
Adelie	Torgersen	39.5	17.4	186	3800	female
Adelie	Torgersen	40.3	18	195	3250	female
Adelie	Torgersen					
Adelie	Torgersen	36.7	19.3	193	3450	female
Adelie	Torgersen	39.3	20.6	190	3650	male
Adelie	Torgersen	38.9	17.8	181	3625	female
Adelie	Torgersen	39.2	19.6	195	4675	male
Adelie	Torgersen	34.1	18.1	193	3475	
Adelie	Torgersen	42	20.2	190	4250	

1—10 of 344 rows

Previous 1 2 3 4 5 ... 35 Next

Add filter

```
reactable(penguins, filterable = TRUE)
```

species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g	sex
Adelie	Torgersen	39.1	18.7	181	3750	male
Adelie	Torgersen	39.5	17.4	186	3800	female
Adelie	Torgersen	40.3	18	195	3250	female
Adelie	Torgersen					
Adelie	Torgersen	36.7	19.3	193	3450	female
Adelie	Torgersen	39.3	20.6	190	3650	male
Adelie	Torgersen	38.9	17.8	181	3625	female
Adelie	Torgersen	39.2	19.6	195	4675	male
Adelie	Torgersen	34.1	18.1	193	3475	
Adelie	Torgersen	42	20.2	190	4250	

Searchable

```
reactable(penguins, searchable = TRUE)
```

Search

species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g	sex
Adelie	Torgersen	39.1	18.7	181	3750	male
Adelie	Torgersen	39.5	17.4	186	3800	female
Adelie	Torgersen	40.3	18	195	3250	female
Adelie	Torgersen					
Adelie	Torgersen	36.7	19.3	193	3450	female
Adelie	Torgersen	39.3	20.6	190	3650	male
Adelie	Torgersen	38.9	17.8	181	3625	female
Adelie	Torgersen	39.2	19.6	195	4675	male
Adelie	Torgersen	34.1	18.1	193	3475	
Adelie	Torgersen	42	20.2	190	4250	

Pagination

```
reactable(penguins, defaultPageSize = 3)
```

species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g	sex
Adelie	Torgersen	39.1	18.7	181	3750	male
Adelie	Torgersen	39.5	17.4	186	3800	female
Adelie	Torgersen	40.3	18	195	3250	female

1—3 of 344 rows

Previous 1 2 3 4 5 ... 115 Next

Page jump

```
reactable(penguins,
          defaultPageSize = 3,
          paginationType = "jump")
```

species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g	sex
Adelie	Torgersen	39.1	18.7	181	3750	male
Adelie	Torgersen	39.5	17.4	186	3800	female
Adelie	Torgersen	40.3	18	195	3250	female

1—3 of 344 rows Previous 1 of 115 Next

Grouping

```
reactable(penguins, groupBy = c("species", "island"))
```

species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g	sex
▶ Adelie (3)						
▶ Gentoo (1)						
▶ Chinstrap (1)						

Aggregate

```
penguins %>%
  reactable(
    groupBy = c("species", "island"),
    columns = list(
      bill_length_mm = colDef(aggregate = "mean",
                              format = colFormat(digits = 2))
    )
  )
```

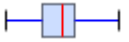
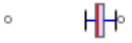
species	island	bill_length_mm	bill_depth_mm	flipper_length_mm	body_mass_g	sex
▶ Adelie (3)		38.81				
▶ Gentoo (1)		47.50				
▶ Chinstrap (1)		48.83				

Sparklines

```
library(sparkline)
table_data <- penguins %>%
  group_by(species) %>%
  summarize(bill_length = list(bill_length_mm)) %>%
  mutate(boxplot = NA,
         sparkline = NA)
table_data
```

```
## # A tibble: 3 × 4
##   species   bill_length boxplot sparkline
##   <fct>     <list>      <lgl>   <lgl>
## 1 Adelie    <dbl [152]> NA      NA
## 2 Chinstrap <dbl [68]>  NA      NA
## 3 Gentoo    <dbl [124]> NA      NA
```

```r
table_data %>%
  reactable(
    columns = list(
      bill_length = colDef(cell = function(value) {
        sparkline(value, type = "bar")
      }),
      boxplot = colDef(cell = function(value, index) {
        sparkline(table_data$bill_length[[index]], type = "box")
      }),
      sparkline = colDef(cell = function(value, index) {
        sparkline(table_data$bill_length[[index]])
      })
    )
  )
```

species	bill_length	boxplot	sparkline
Adelie			
Chinstrap			
Gentoo			

Lots more!

Idea of today is not to teach you everything, but to give you an idea of what's possible. Check out the documentation for more information.

Fonts

General advice

- Match your plot fonts to your text body font
- Use different fonts to distinguish things
    - Specifically code
    - Consider different fonts for different heading levels, and/or to distinguish headers from the body
- **Always** choose a sans–serif font for code
- Explore and try – it makes a big impact on the overall look/feel (bigger than you may expect if you haven't played with fonts much before)
- Try not to get sucked into too deep of a rabbit hole

{ragg}

Alternative device to Cairo, png, etc.

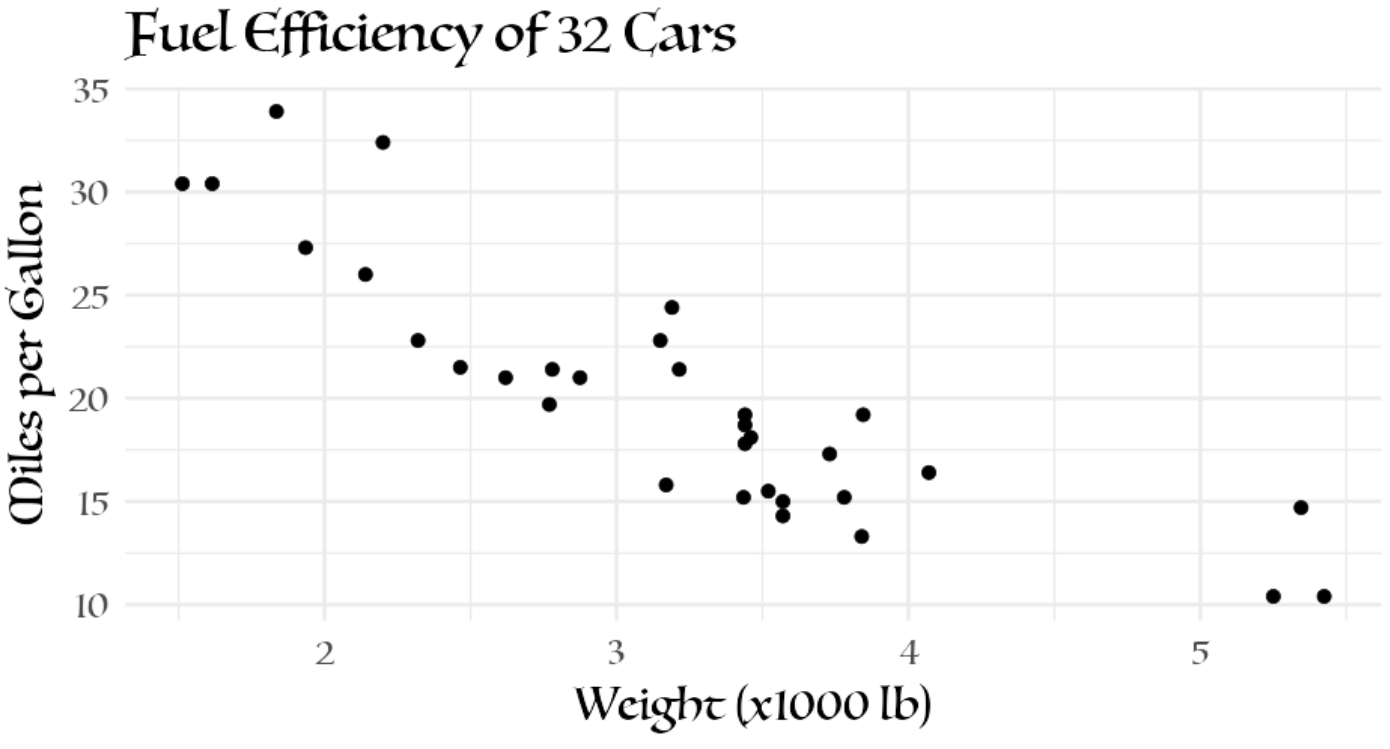
See the announcement here

After install, be sure to set *Global Options* > *General* > *Graphics* to *AGG*

Use with RMarkdown with `knitr::opts_chunk$set(dev = "ragg_png")`

Will automatically detect fonts you have installed on your computer

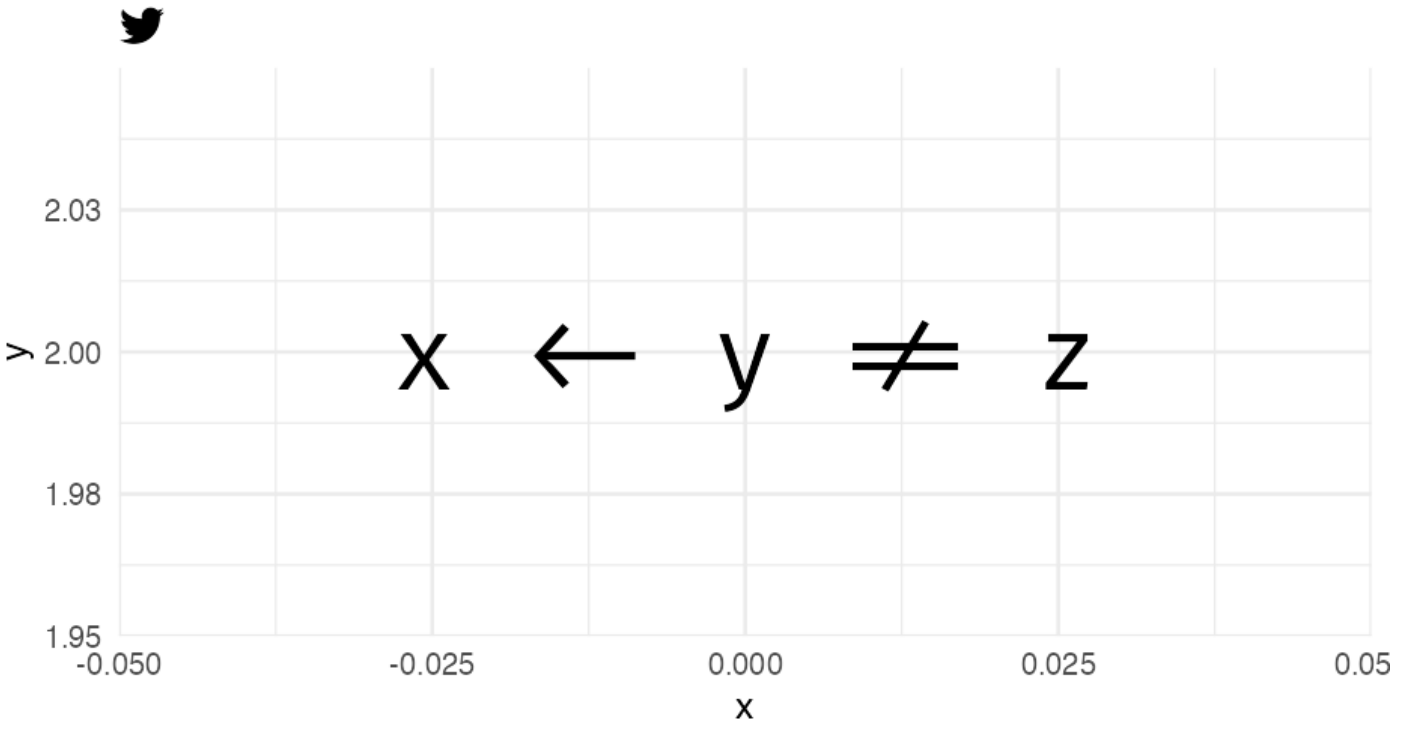
```
ggplot(mtcars, aes(wt, mpg)) +
  geom_point() +
  labs(title = "Fuel Efficiency of 32 Cars",
       x = "Weight (x1000 lb)",
       y = "Miles per Gallon") +
  theme(text = element_text(family = "Luminari", size = 30))
```



Support for lots of things!

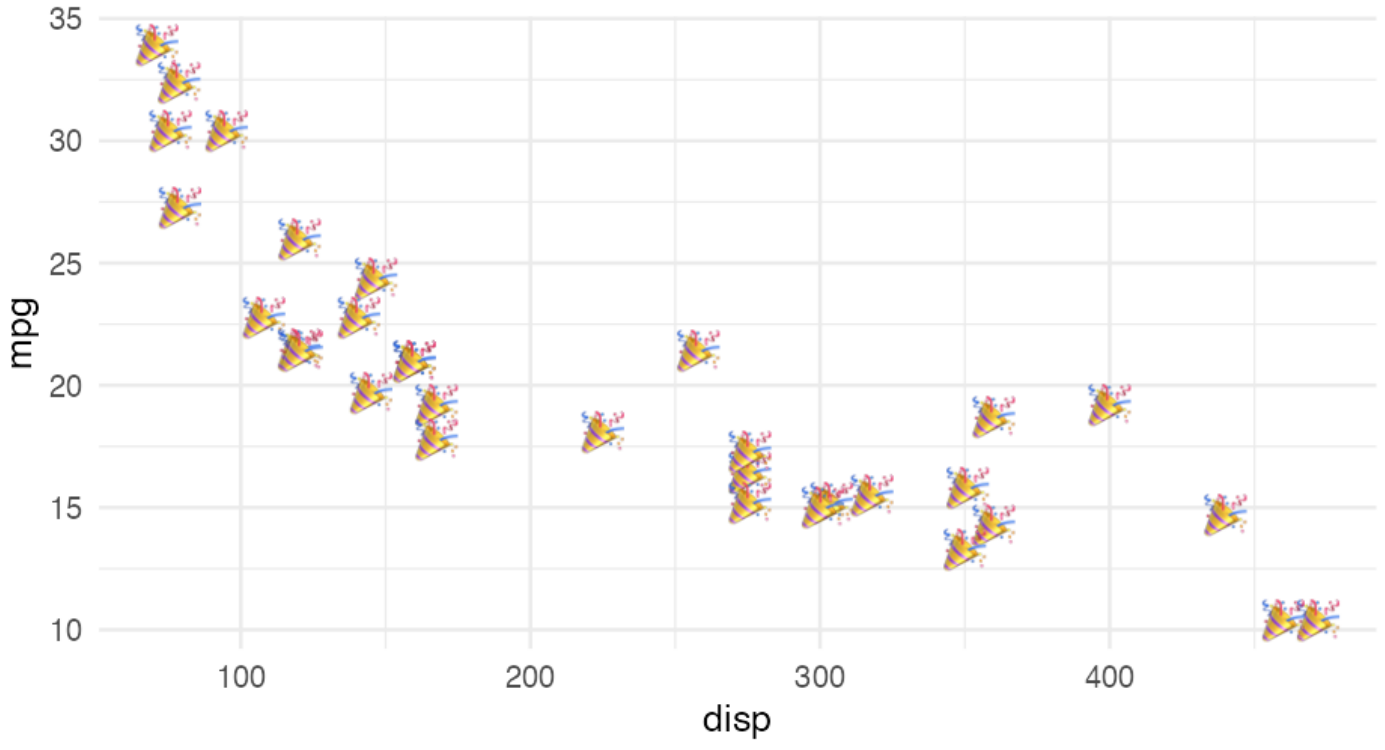
Ligatures and font–awesome icons

```
library(ragg)

ggplot() +
  geom_text(
    aes(x = 0, y = 2, label = "x <- y != z"),
    family = "Fira Code"
  ) +
  labs(title = "twitter") +
  theme(
    plot.title = element_text(
      family = "Font Awesome 5 brands"
    )
  )
```


x ← y ≠ z
2.03
2.00
1.98
1.95
y
-0.050
-0.025
0.000
0.025
0.05
x

emojis

```
ggplot(mtcars, aes(disp, mpg)) +
  geom_text(label = "🎉",
            family = "Apple Color Emoji",
            size = 10)
```



Google fonts

https://fonts.google.com

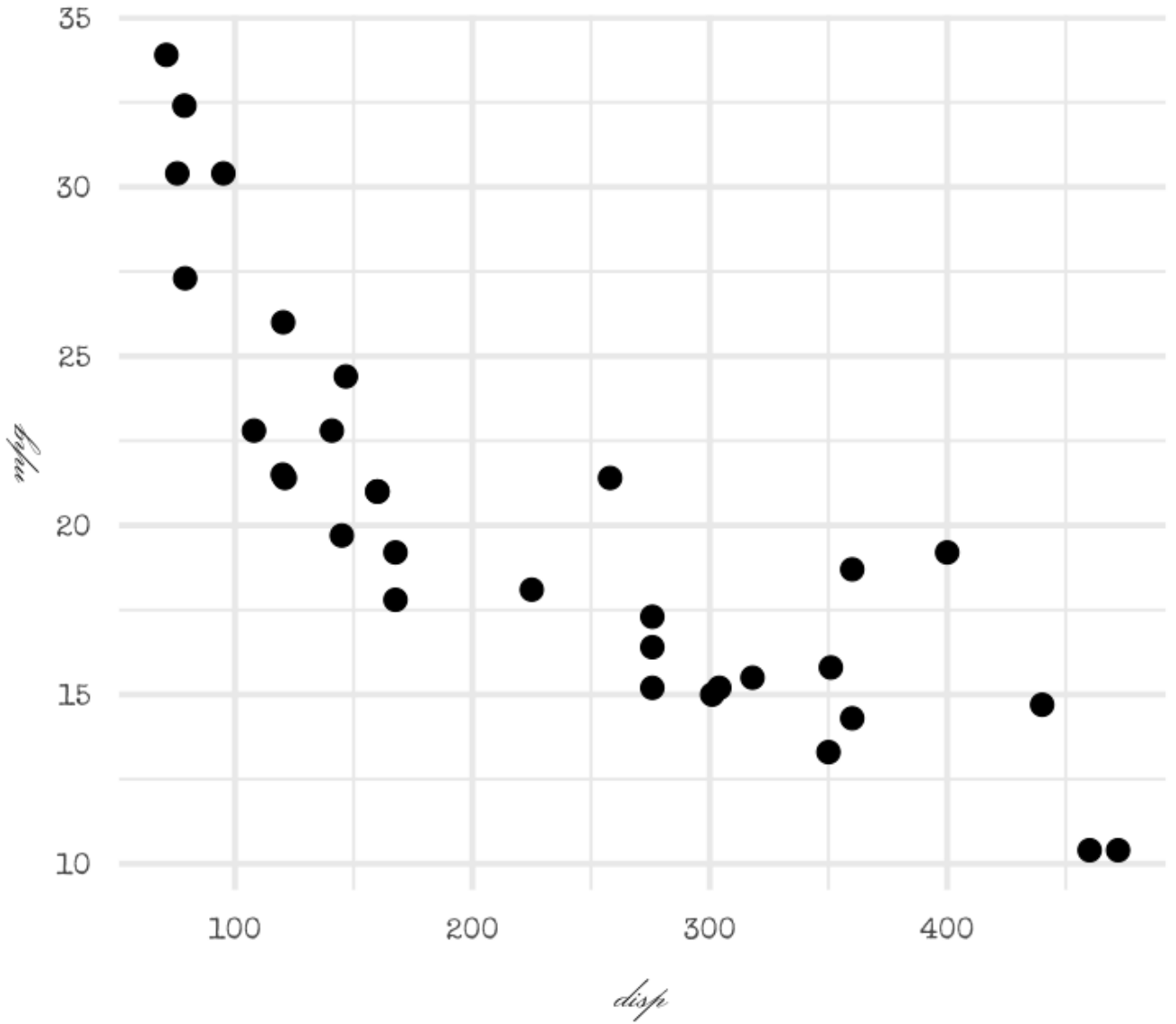
- Open source, designed for the web
- Good place to explore fonts
- Can be incorporated via the `{showtext}` package!

{showtext} example

```
devtools::install_github("yixuan/showtext")

library(showtext)

font_add_google('Monsieur La Doulaise', "mld")
font_add_google('Special Elite', "se")

showtext_auto()
quartz()

ggplot(mtcars, aes(disp, mpg)) +
  geom_point() +
  labs(title = "An amazing title",
       subtitle = "with the world's most boring dataset") +
  theme(plot.subtitle = element_text(size = 18, family = "se"),
        plot.title = element_text(size = 22, family = "mld"),
        axis.title = element_text(size = 18, family = "mld"),
        axis.text.x = element_text(size = 12, family = "se"),
        axis.text.y = element_text(size = 12, family = "se"))
```

An amazing title

with the world's most boring dataset



Practice

- Create a simple plot
- Change the font to something on your computer (e.g., "Times New Roman")
- Try importing and using a google font with **showtext**
- Try using different fonts for the title and subtitle

05:00

Why fonts matter

A few examples of epic fails

h/t Will Chase

Megaflicks


i will always find you
I WILL ALWAYS FIND YOU
FONT MATTERS.


You'll Always
Be Mine
YOU'LL
ALWAYS
BE
MINE

Quick aside

Change the font of your R Markdown!

Create a CSS code chunk – write tiny bit of CSS – voila!

```
@import url('https://fonts.googleapis.com/css?family=Akronim&dis

body {
  font-family: 'Akronim', cursive;
}
```

We'll talk about this more next week.

Render!

Aside

I actually did this for these slides to make the tables a bit smaller!

````
24
25 ```{css echo = FALSE}
26 table {
27   font-size: 1rem;
28 }
29 ```
30
````

Resource for learning more

- I'm not an expert on fonts. I have mostly just picked what looks nice to me.
- Consider the accesibility of the font (good resource here)

Best I've heard of is practical typography

Identify fonts

Use others work to help you – I found the font for these slides from a different theme that I liked.

Use google chrome's developer tools to help!

Next time: Dashboards, websites, etc.