Summarizing Data

Computational Mathematics and Statistics

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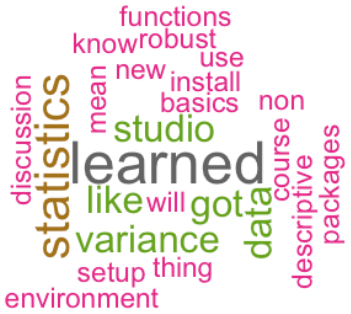
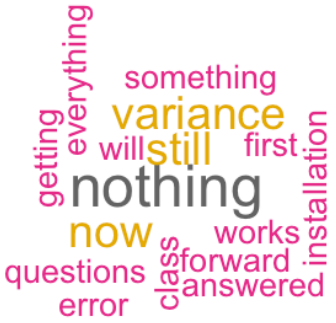
One Minute Paper Results

What was the most important thing you learned during this class?

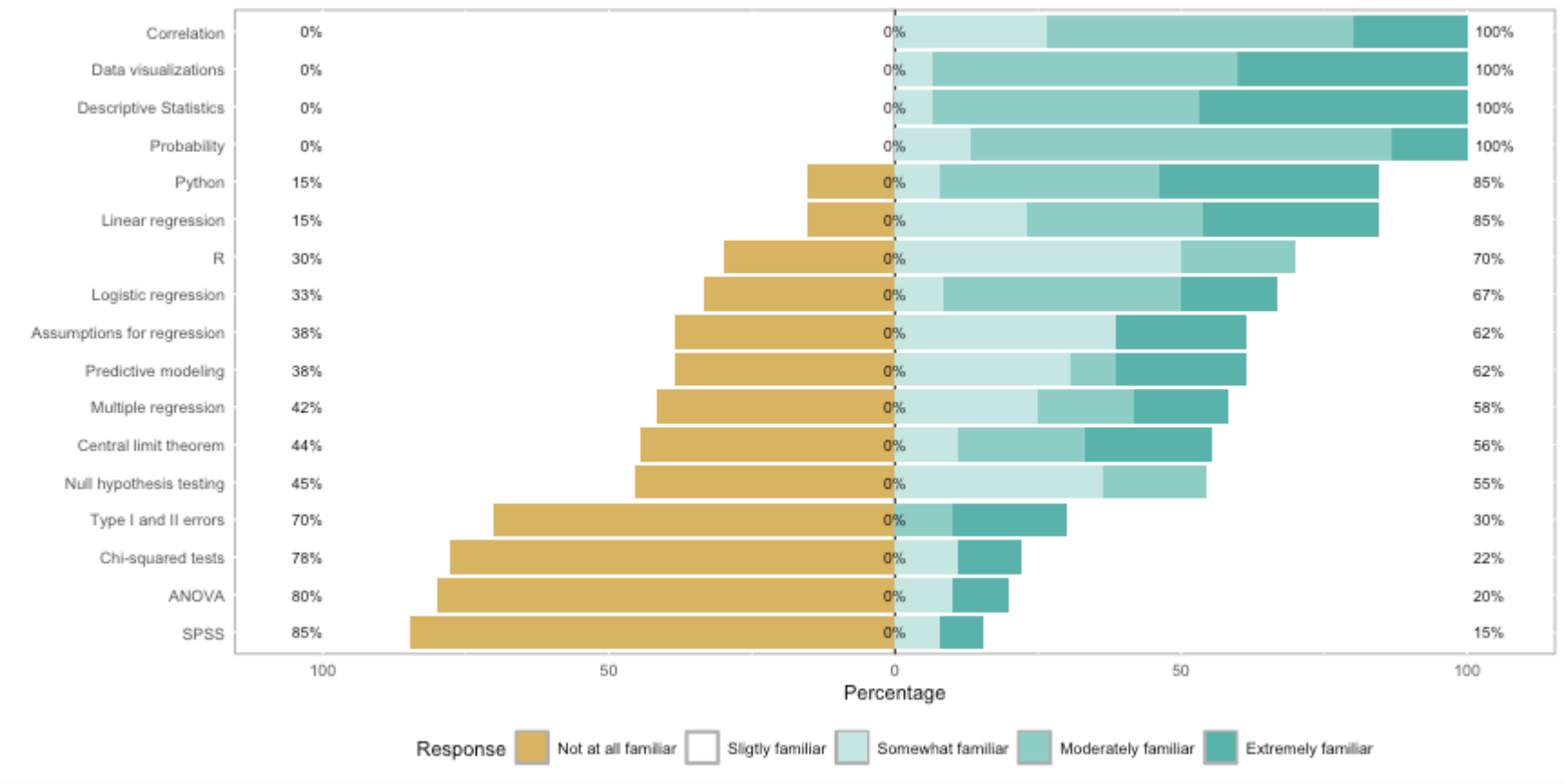


What important question remains unanswered for you?



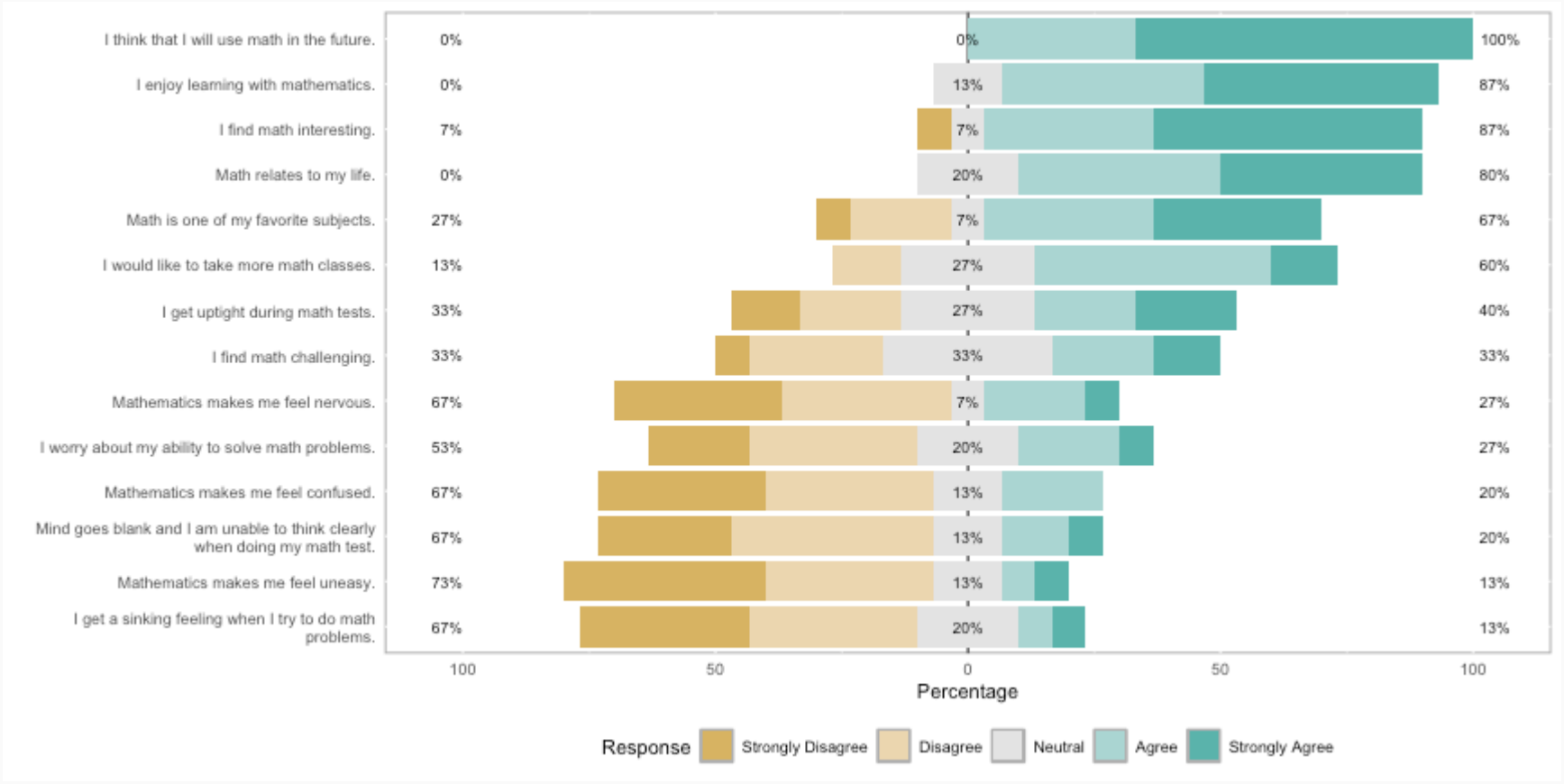
Familiarity with Statistical Topics

```
likert(stats.results) %>% plot(center = 2.5)
```



Math Anxiety Survey Scale

```
likert(mass.results) %>% plot()
```



About `legosets`

To install the `brickset` package:

```
remotes::install_github('jbryer/brickset')
```

To load the load the `legosets` dataset.

```
data('legosets', package = 'brickset')
```

The `legosets` data has 19409 observations of 36 variables.

```
names(legosets)
```

```
##  [1] "setID"                "number"               "numberVariant"
##  [4] "name"                 "year"                 "theme"
##  [7] "themeGroup"           "subtheme"             "category"
## [10] "released"             "pieces"               "minifigs"
## [13] "bricksetURL"          "rating"               "reviewCount"
## [16] "packagingType"        "availability"         "agerange_min"
## [19] "thumbnailURL"         "imageURL"             "US_retailPrice"
## [22] "US_dateFirstAvailable" "US_dateLastAvailable" "UK_retailPrice"
## [25] "UK_dateFirstAvailable" "UK_dateLastAvailable" "CA_retailPrice"
## [28] "CA_dateFirstAvailable" "CA_dateLastAvailable" "DE_retailPrice"
## [31] "DE_dateFirstAvailable" "DE_dateLastAvailable" "height"
## [34] "width"                "depth"                "weight"
```

Structure (`str`)

```
str(legosets)
```

```
## 'data.frame':    19409 obs. of  36 variables:
##  $ setID                : int  7693 7695 7697 7698 25534 7418 7419 6020 22704 7421 ...
##  $ number               : chr  "1" "2" "3" "4" ...
##  $ numberVariant        : int  8 8 6 4 6 1 1 1 3 4 ...
##  $ name                 : chr  "Small house set" "Medium house set" "Medium house set" "Large house set" ...
##  $ year                 : int  1970 1970 1970 1970 1970 1970 1970 1970 1970 1970 ...
##  $ theme                : chr  "Minitalia" "Minitalia" "Minitalia" "Minitalia" ...
##  $ themeGroup           : chr  "Vintage" "Vintage" "Vintage" "Vintage" ...
##  $ subtheme             : chr  NA NA NA NA ...
##  $ category             : chr  "Normal" "Normal" "Normal" "Normal" ...
##  $ released             : logi  TRUE TRUE TRUE TRUE TRUE TRUE ...
##  $ pieces               : int  67 109 158 233 NA 1 1 60 65 NA ...
##  $ minifigs             : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ bricksetURL          : chr  "https://brickset.com/sets/1-8" "https://brickset.com/sets/2-8" "https://brickset.com/sets/3-6" "https://brickset.com/sets/4-4" ...
##  $ rating               : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ reviewCount          : int  0 0 1 0 0 0 0 0 0 0 ...
##  $ packagingType        : chr  "{Not specified}" "{Not specified}" "{Not specified}" "{Not specified}" ...
##  $ availability         : chr  "{Not specified}" "{Not specified}" "{Not specified}" "{Not specified}" ...
##  $ agerange_min         : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ thumbnailURL         : chr  "https://images.brickset.com/sets/small/1-8.jpg" "https://images.brickset.com/sets/small/2-8.jpg" "https://images.brickset.com/sets/small/3-6.jpg" "https:
##  $ imageURL             : chr  "https://images.brickset.com/sets/images/1-8.jpg" "https://images.brickset.com/sets/images/2-8.jpg" "https://images.brickset.com/sets/images/3-6.jpg" "ht
##  $ US_retailPrice       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ US_dateFirstAvailable: Date, format: NA NA ...
##  $ US_dateLastAvailable : Date, format: NA NA ...
##  $ UK_retailPrice       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ UK_dateFirstAvailable: Date, format: NA NA ...
##  $ UK_dateLastAvailable : Date, format: NA NA ...
##  $ CA_retailPrice       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ CA_dateFirstAvailable: Date, format: NA NA ...
##  $ CA_dateLastAvailable : Date, format: NA NA ...
##  $ DE_retailPrice       : num  NA NA NA NA NA NA NA NA NA NA ...
##  $ DE_dateFirstAvailable: Date, format: NA NA ...
##  $ DE_dateLastAvailable : Date, format: NA NA ...
##  $ height               : num  NA NA NA NA NA ...
##  $ width                : num  NA NA NA NA NA ...
```

RStudio Eenvironment tab can help

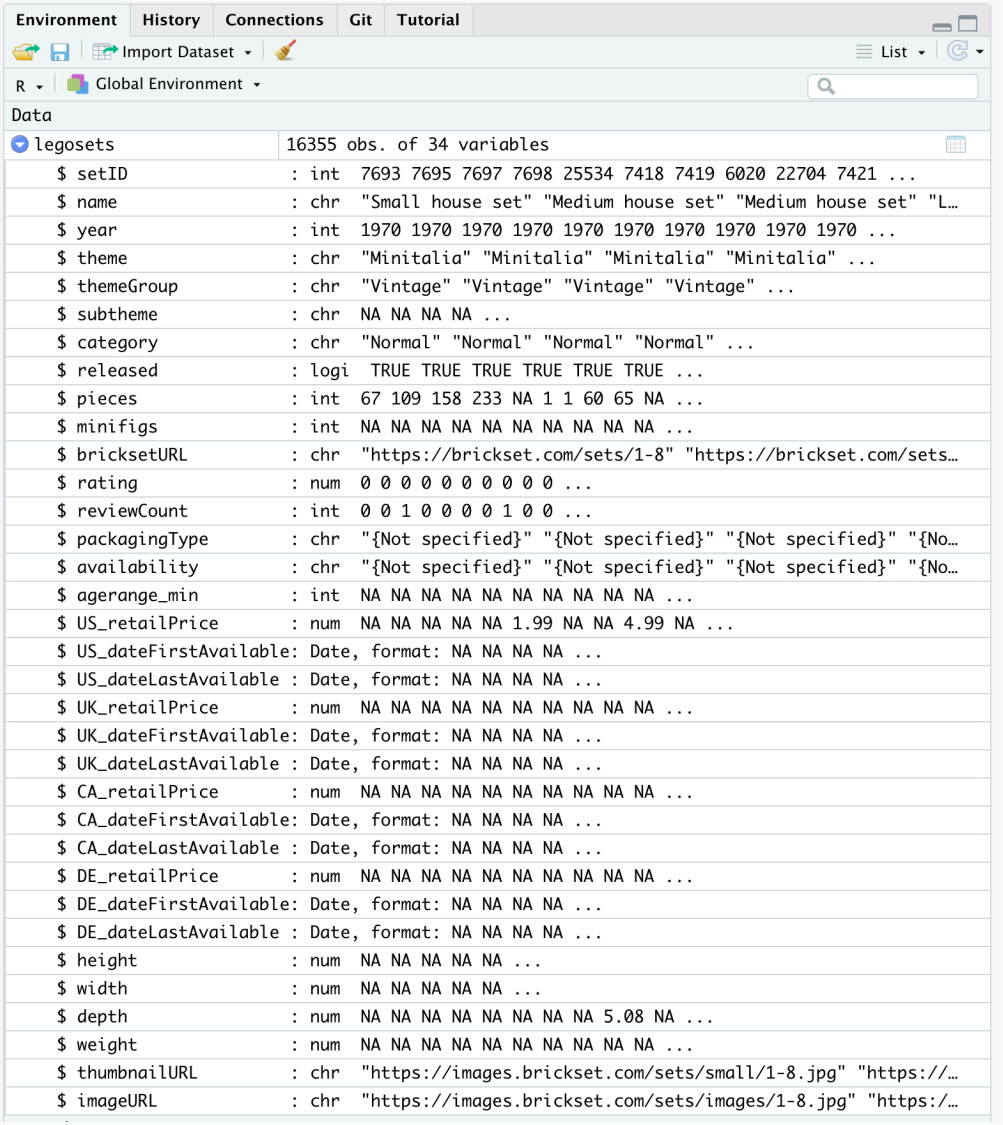


Table View

Show 10 entries

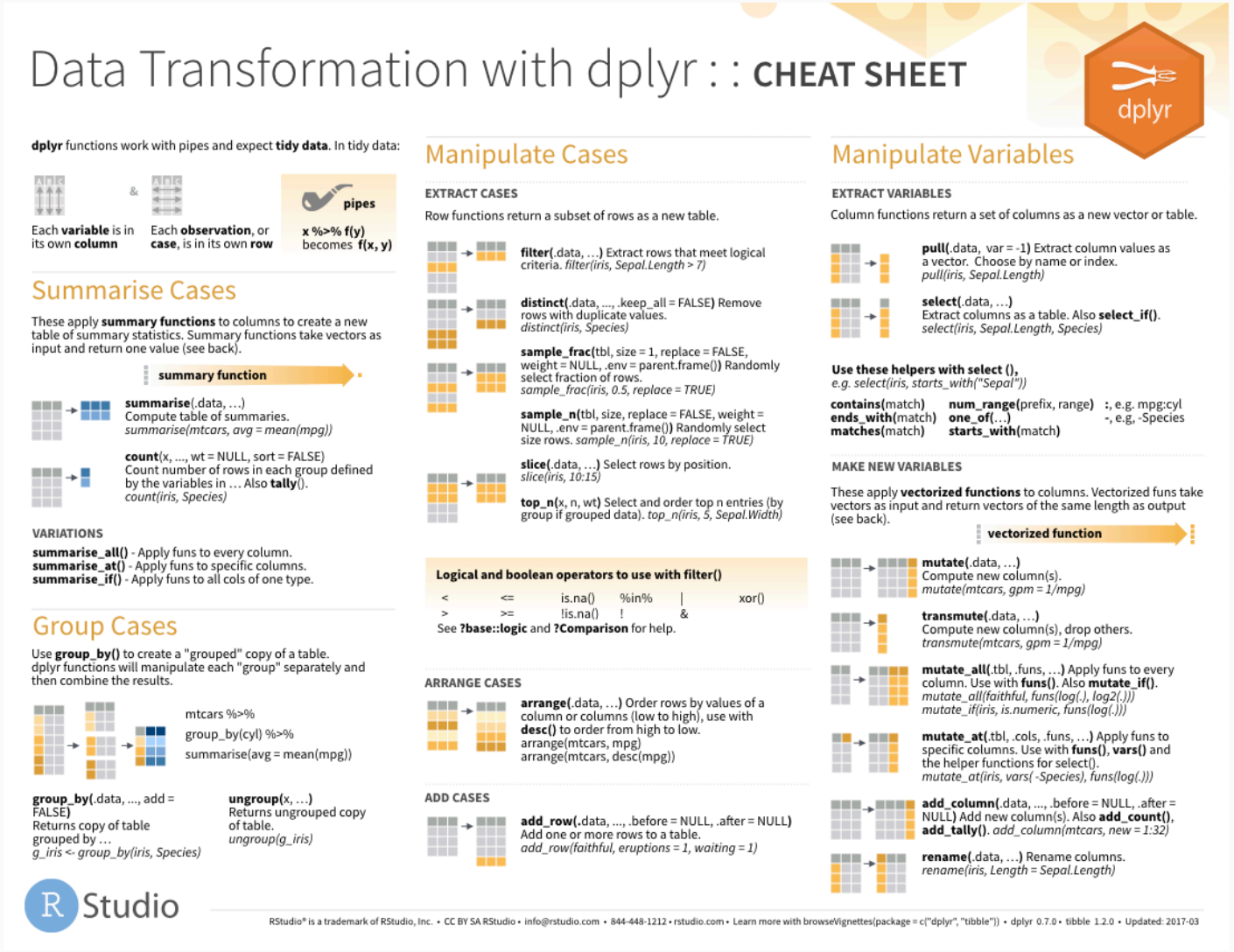
Search:

	setID	name	year	theme	themeGroup	category	US_retailPrice	pieces	minifigs	rating
1	1137	The Meadowsweet's' Home	1999	Duplo	Pre-school	Normal		41	4	0
2	31564	Spider-Man & Doctor Octopus Mech Battle	2021	Marvel Super Heroes	Licensed	Normal	19.99	305	2	3.4
3	6832	Garbage Truck	2009	Duplo	Pre-school	Normal	16.99	12	1	0
4	1654	NHL Championship Challenge	2004	Sports	Modern day	Normal		374	8	0
5	6383	LEGO Star Wars: The Video Game	2005	Gear	Miscellaneous	Gear				0
6	29916	Bricks and Animals	2020	Classic	Basic	Normal	59.99	1500		4
7	5571	Deep Sea Treasure Hunter	2007	Aqua Raiders	Action/Adventure	Normal	4.99	75	1	4
8	26320	Journal with White Band	2016	Gear	Miscellaneous	Gear	19.99			0
9	4795	Hans Christian Andersen Bucket	2005	Creator	Model making	Normal		500		0
10	9247	Racing Car	2012	City	Modern day	Normal		35	1	3

Showing 1 to 10 of 100 entries

Previous 1 2 3 4 5 ... 10 Next

Data Wrangling Cheat Sheet



Data Transformation with dplyr : : CHEAT SHEET

dplyr

dplyr functions work with pipes and expect **tidy data**. In tidy data:

Each **variable** is in its own **column** & Each **observation**, or **case**, is in its own **row**

pipes
x %>% f(y) becomes **f(x, y)**

Summarise Cases

These apply **summary functions** to columns to create a new table of summary statistics. Summary functions take vectors as input and return one value (see back).

summary function

summarise(.data, …)
Compute table of summaries.
summarise(mtcars, avg = mean(mpg))

count(x, ..., wt = NULL, sort = FALSE)
Count number of rows in each group defined by the variables in … Also **tally**().
count(iris, Species)

VARIATIONS

summarise_all() - Apply funs to every column.
summarise_at() - Apply funs to specific columns.
summarise_if() - Apply funs to all cols of one type.

Group Cases

Use **group_by()** to create a "grouped" copy of a table. dplyr functions will manipulate each "group" separately and then combine the results.

```
mtcars %>%
group_by(cyl) %>%
summarise(avg = mean(mpg))
```

group_by(.data, ..., add = FALSE)
Returns copy of table grouped by …
g_iris <- group_by(iris, Species)

ungroup(x, …)
Returns ungrouped copy of table.
ungroup(g_iris)

Manipulate Cases

EXTRACT CASES

Row functions return a subset of rows as a new table.

filter(.data, …) Extract rows that meet logical criteria. *filter(iris, Sepal.Length > 7)*

distinct(.data, ..., .keep_all = FALSE) Remove rows with duplicate values.
distinct(iris, Species)

sample_frac(tbl, size = 1, replace = FALSE, weight = NULL, .env = parent.frame()) Randomly select fraction of rows.
sample_frac(iris, 0.5, replace = TRUE)

sample_n(tbl, size, replace = FALSE, weight = NULL, .env = parent.frame()) Randomly select size rows. *sample_n(iris, 10, replace = TRUE)*

slice(.data, …) Select rows by position.
slice(iris, 10:15)

top_n(x, n, wt) Select and order top n entries (by group if grouped data). *top_n(iris, 5, Sepal.Width)*

Logical and boolean operators to use with filter()

<	<=	is.na()	%in%	|	xor()
>	>=	!is.na()	!	&	

See **?base::logic** and **?Comparison** for help.

ARRANGE CASES

arrange(.data, …) Order rows by values of a column or columns (low to high), use with **desc()** to order from high to low.
arrange(mtcars, mpg)
arrange(mtcars, desc(mpg))

ADD CASES

add_row(.data, ..., .before = NULL, .after = NULL) Add one or more rows to a table.
add_row(faithful, eruptions = 1, waiting = 1)

Manipulate Variables

EXTRACT VARIABLES

Column functions return a set of columns as a new vector or table.

pull(.data, var = -1) Extract column values as a vector. Choose by name or index.
pull(iris, Sepal.Length)

select(.data, …)
Extract columns as a table. Also **select_if()**.
select(iris, Sepal.Length, Species)

Use these helpers with select (),
e.g. select(iris, starts_with("Sepal"))

contains(match)
ends_with(match)
matches(match)
num_range(prefix, range)
one_of(…)
starts_with(match)
:, e.g. mpg:cyl
-, e.g, -Species

MAKE NEW VARIABLES

These apply **vectorized functions** to columns. Vectorized funs take vectors as input and return vectors of the same length as output (see back).

vectorized function

mutate(.data, …)
Compute new column(s).
mutate(mtcars, gpm = 1/mpg)

transmute(.data, …)
Compute new column(s), drop others.
transmute(mtcars, gpm = 1/mpg)

mutate_all(.tbl, .funs, …) Apply funs to every column. Use with **funs()**. Also **mutate_if()**.
mutate_all(faithful, funs(log(.), log2(.)))
mutate_if(iris, is.numeric, funs(log(.)))

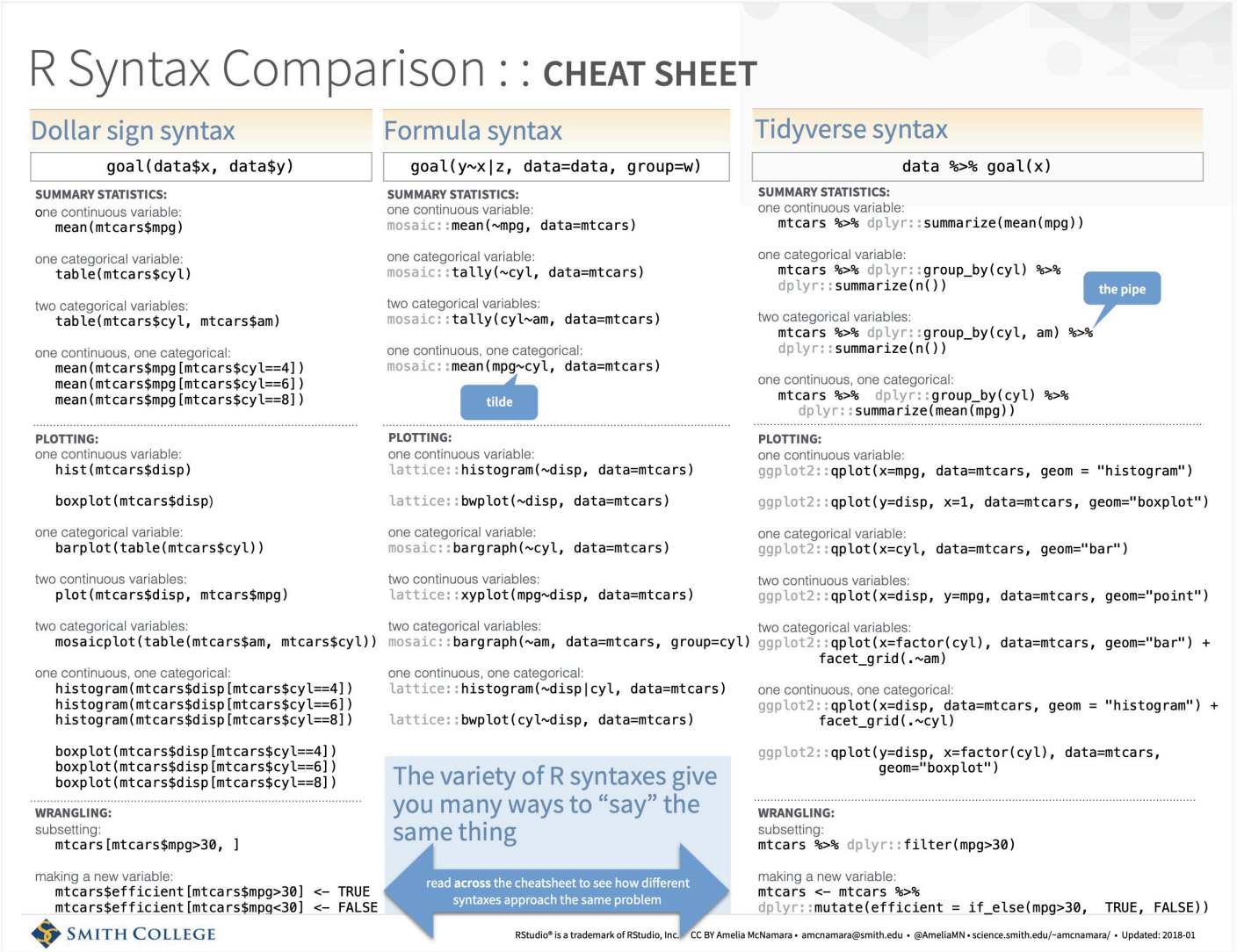
mutate_at(.tbl, .cols, .funs, …) Apply funs to specific columns. Use with **funs()**, **vars()** and the helper functions for select().
mutate_at(iris, vars(-Species), funs(log(.)))

add_column(.data, ..., .before = NULL, .after = NULL) Add new column(s). Also **add_count()**, **add_tally()**. *add_column(mtcars, new = 1:32)*

rename(.data, …) Rename columns.
rename(iris, Length = Sepal.Length)

RStudio

Tidyverse vs Base R



R Syntax Comparison : : CHEAT SHEET

Dollar sign syntax

`goal(data$x, data$y)`

SUMMARY STATISTICS:

one continuous variable:
```
mean(mtcars$mpg)
```

one categorical variable:
```
table(mtcars$cyl)
```

two categorical variables:
```
table(mtcars$cyl, mtcars$am)
```

one continuous, one categorical:
```
mean(mtcars$mpg[mtcars$cyl==4])
mean(mtcars$mpg[mtcars$cyl==6])
mean(mtcars$mpg[mtcars$cyl==8])
```

PLOTTING:

one continuous variable:
```
hist(mtcars$disp)

boxplot(mtcars$disp)
```

one categorical variable:
```
barplot(table(mtcars$cyl))
```

two continuous variables:
```
plot(mtcars$disp, mtcars$mpg)
```

two categorical variables:
```
mosaicplot(table(mtcars$am, mtcars$cyl))
```

one continuous, one categorical:
```
histogram(mtcars$disp[mtcars$cyl==4])
histogram(mtcars$disp[mtcars$cyl==6])
histogram(mtcars$disp[mtcars$cyl==8])

boxplot(mtcars$disp[mtcars$cyl==4])
boxplot(mtcars$disp[mtcars$cyl==6])
boxplot(mtcars$disp[mtcars$cyl==8])
```

WRANGLING:

subsetting:
```
mtcars[mtcars$mpg>30, ]
```

making a new variable:
```
mtcars$efficient[mtcars$mpg>30] <- TRUE
mtcars$efficient[mtcars$mpg<30] <- FALSE
```

Formula syntax

`goal(y~x|z, data=data, group=w)`

SUMMARY STATISTICS:

one continuous variable:
```
mosaic::mean(~mpg, data=mtcars)
```

one categorical variable:
```
mosaic::tally(~cyl, data=mtcars)
```

two categorical variables:
```
mosaic::tally(cyl~am, data=mtcars)
```

one continuous, one categorical:
```
mosaic::mean(mpg~cyl, data=mtcars)
```

tilde

PLOTTING:

one continuous variable:
```
lattice::histogram(~disp, data=mtcars)

lattice::bwplot(~disp, data=mtcars)
```

one categorical variable:
```
mosaic::bargraph(~cyl, data=mtcars)
```

two continuous variables:
```
lattice::xyplot(mpg~disp, data=mtcars)
```

two categorical variables:
```
mosaic::bargraph(~am, data=mtcars, group=cyl)
```

one continuous, one categorical:
```
lattice::histogram(~disp|cyl, data=mtcars)

lattice::bwplot(cyl~disp, data=mtcars)
```

The variety of R syntaxes give you many ways to "say" the same thing

read **across** the cheatsheet to see how different syntaxes approach the same problem

Tidyverse syntax

`data %>% goal(x)`

SUMMARY STATISTICS:

one continuous variable:
```
mtcars %>% dplyr::summarize(mean(mpg))
```

one categorical variable:
```
mtcars %>% dplyr::group_by(cyl) %>%
  dplyr::summarize(n())
```

the pipe

two categorical variables:
```
mtcars %>% dplyr::group_by(cyl, am) %>%
  dplyr::summarize(n())
```

one continuous, one categorical:
```
mtcars %>%  dplyr::group_by(cyl) %>%
   dplyr::summarize(mean(mpg))
```

PLOTTING:

one continuous variable:
```
ggplot2::qplot(x=mpg, data=mtcars, geom = "histogram")

ggplot2::qplot(y=disp, x=1, data=mtcars, geom="boxplot")
```

one categorical variable:
```
ggplot2::qplot(x=cyl, data=mtcars, geom="bar")
```

two continuous variables:
```
ggplot2::qplot(x=disp, y=mpg, data=mtcars, geom="point")
```

two categorical variables:
```
ggplot2::qplot(x=factor(cyl), data=mtcars, geom="bar") +
        facet_grid(.~am)
```

one continuous, one categorical:
```
ggplot2::qplot(x=disp, data=mtcars, geom = "histogram") +
        facet_grid(.~cyl)

ggplot2::qplot(y=disp, x=factor(cyl), data=mtcars,
               geom="boxplot")
```

WRANGLING:

subsetting:
```
mtcars %>% dplyr::filter(mpg>30)
```

making a new variable:
```
mtcars <- mtcars %>%
dplyr::mutate(efficient = if_else(mpg>30,  TRUE, FALSE))
```

SMITH COLLEGE

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Pipes %>% and |>

The pipe operator (`%>%`) introduced with the `magrittr` R package allows for the chaining of R operations. Base R has now added their own pipe operator (`|>`). They take the output from the left-hand side and passes it as the first parameter to the function on the right-hand side.

You can do this in two steps:

```
tab_out <- table(legosets$category)
prop.table(tab_out)
```

Or as nested function calls.

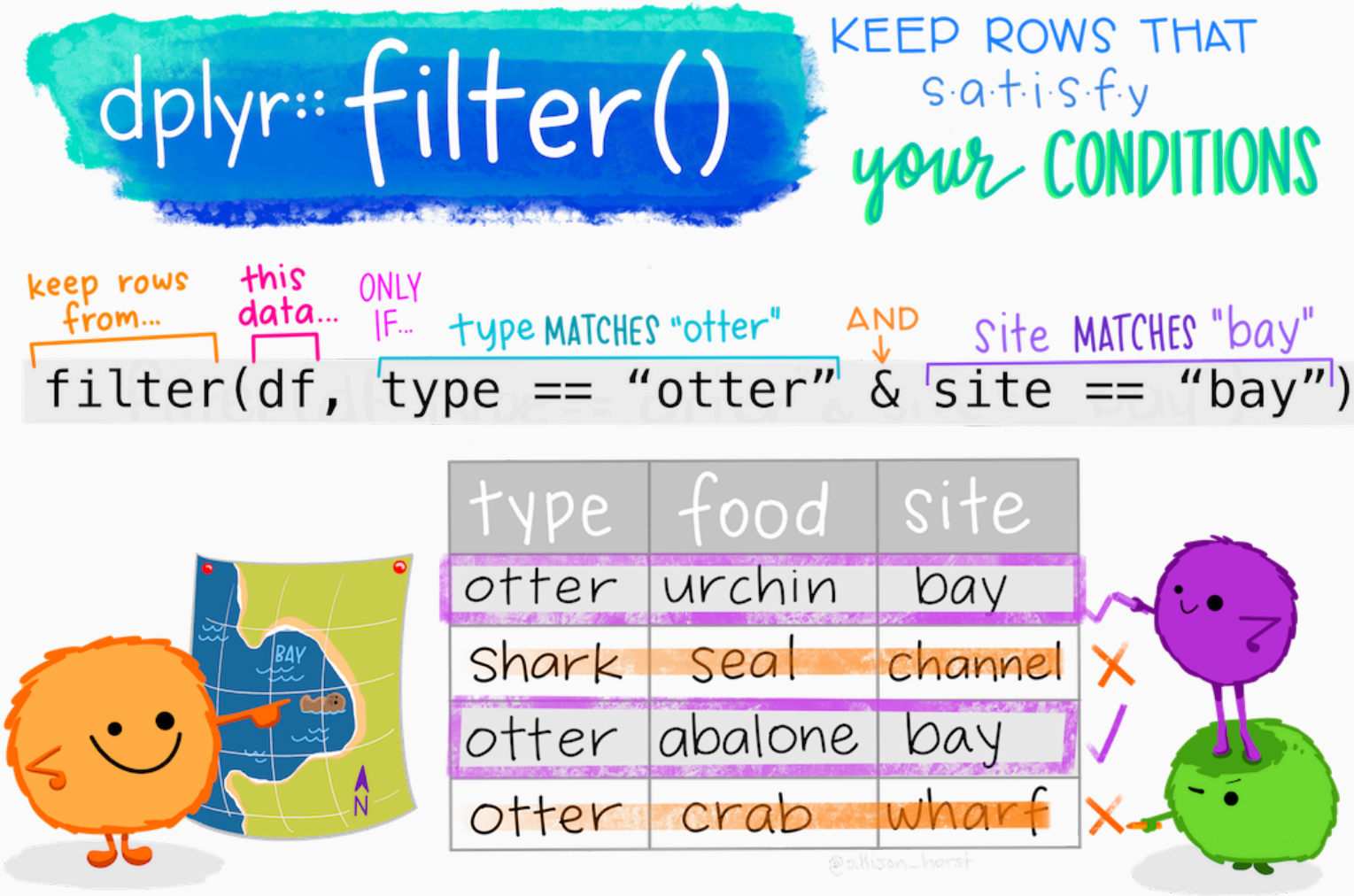
```
prop.table(table(legosets$category))
```

Using the pipe (`|>`) operator we can chain these calls in a what is arguably a more readable format:

```
table(legosets$category) |> prop.table()
```

```
##
##        Book  Collection    Extended        Gear      Normal       Other
## 0.034468546 0.031377196 0.028749549 0.154515946 0.684682364 0.062599825
```

Filter


dplyr::filter()
KEEP ROWS THAT satisfy your CONDITIONS
keep rows from...
this data...
ONLY IF...
type MATCHES "otter"
AND
site MATCHES "bay"
filter(df, type == "otter" & site == "bay")
BAY
N
type food site
otter urchin bay
shark seal channel
otter abalone bay
otter crab wharf
@allison_horst

Logical Operators

- `!a` - TRUE if a is FALSE
- `a == b` - TRUE if a and be are equal
- `a != b` - TRUE if a and b are not equal
- `a > b` - TRUE if a is larger than b, but not equal
- `a >= b` - TRUE if a is larger or equal to b
- `a < b` - TRUE if a is smaller than be, but not equal
- `a <= b` - TRUE if a is smaller or equal to b
- `a %in% b` - TRUE if a is in b where b is a vector

```
which( letters %in% c('a','e','i','o','u') )
```

```
## [1]  1  5  9 15 21
```

- `a | b` - TRUE if a *or* b are TRUE
- `a & b` - TRUE if a *and* b are TRUE
- `isTRUE(a)` - TRUE if a is TRUE

Filter

dplyr

```
mylego <- legosets %>% filter(themeGroup == 'Educational' & year > 2015)
```

Base R

```
mylego <- legosets[legosets$themeGroups == 'Educaitonal' & legosets$year > 2015,]
```

```
nrow(mylego)
```

```
## [1] 99
```

Select

dplyr

```
mylego <- mylego %>% select(setID, pieces, theme, availability, US_retailPrice, minifigs)
```

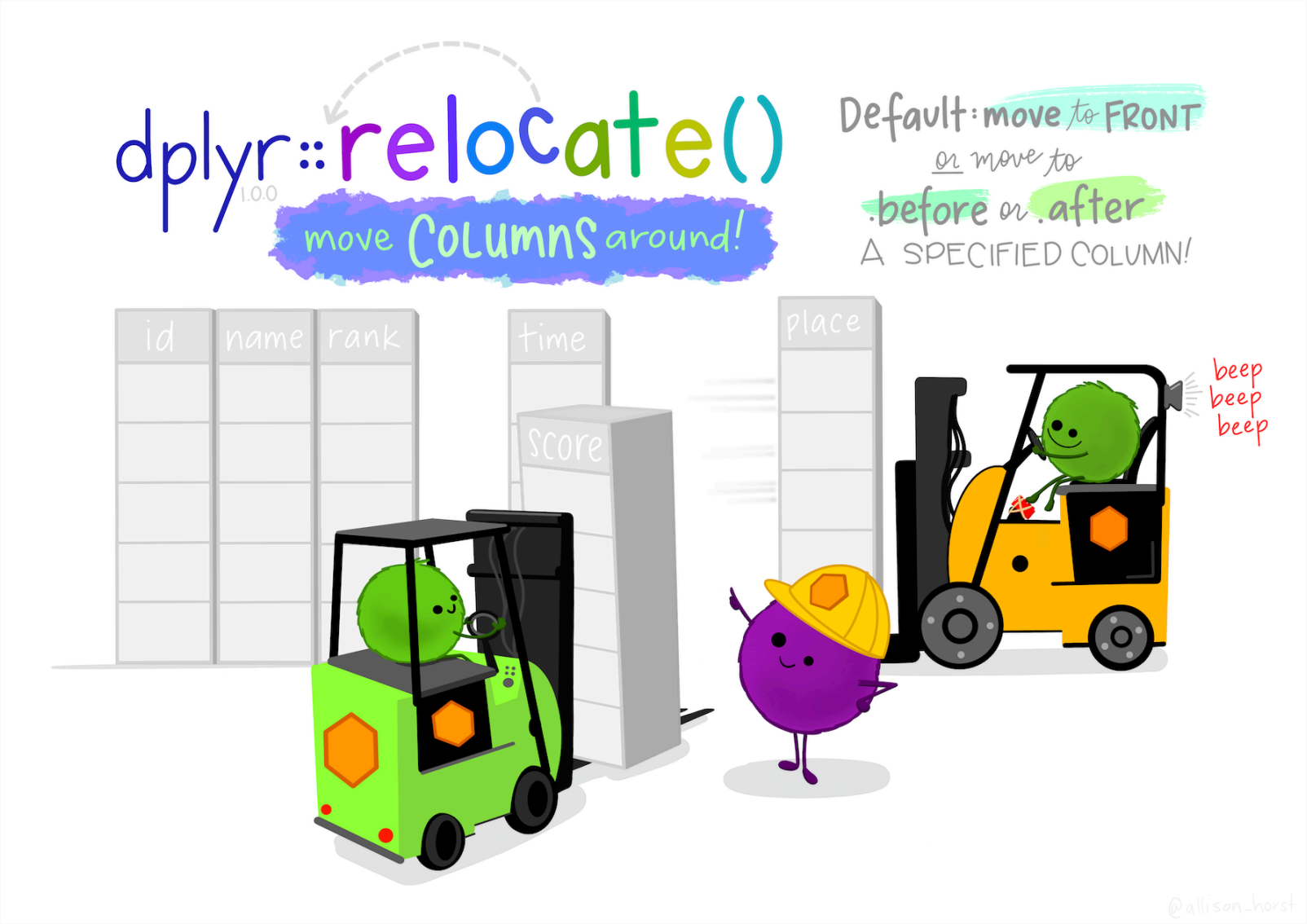
Base R

```
mylego <- mylego[,c('setID', 'pieces', 'theme', 'availability', 'US_retailPrice', 'minifigs')]
```

```
head(mylego, n = 4)
```

```
##   setID pieces     theme    availability US_retailPrice minifigs
## 1 26803    103 Education {Not specified}             NA        6
## 2 26689    142 Education {Not specified}             NA        4
## 3 26804     98 Education {Not specified}             NA        6
## 4 26277    188 Education     Educational          94.95       NA
```

Relocate


dplyr::relocate()
1.0.0
move columns around!
Default: move to FRONT
or move to
.before or .after
A SPECIFIED COLUMN!
id
name
rank
time
score
place
beep
beep
beep
@allison_horst

Relocate

dplyr

```
mylego %>% relocate(where(is.numeric), .after = where(is.character)) %>% head(n = 3)
```

```
##       theme    availability setID pieces US_retailPrice minifigs
## 1 Education {Not specified} 26803    103             NA        6
## 2 Education {Not specified} 26689    142             NA        4
## 3 Education {Not specified} 26804     98             NA        6
```

Base R

```
mylego2 <- mylego[,c('theme', 'availability', 'setID', 'pieces', 'US_retailPrice', 'minifigs')]
head(mylego2, n = 3)
```

```
##       theme    availability setID pieces US_retailPrice minifigs
## 1 Education {Not specified} 26803    103             NA        6
## 2 Education {Not specified} 26689    142             NA        4
## 3 Education {Not specified} 26804     98             NA        6
```

Rename

dplyr::rename()

RENAME COLUMNS*

```
df %>% rename(lair = site)
```

~~species~~ nemesis	status	~~site~~ lair
narwhal	unknown	ocean
chicken	active	coop
pika	active	mountain

*See **rename_with()** to rename using a function.

Rename

dplyr

```
mylego %>% dplyr::rename(USD = US_retailPrice) %>% head(n = 3)
```

```
##   setID pieces     theme    availability USD minifigs
## 1 26803    103 Education {Not specified}  NA        6
## 2 26689    142 Education {Not specified}  NA        4
## 3 26804     98 Education {Not specified}  NA        6
```

Base R

```
names(mylego2)[5] <- 'USD'
head(mylego2, n = 3)
```

```
##       theme    availability setID pieces USD minifigs
## 1 Education {Not specified} 26803    103  NA        6
## 2 Education {Not specified} 26689    142  NA        4
## 3 Education {Not specified} 26804     98  NA        6
```

Mutate


dplyr::mutate
add Column(s),
keep existing.
A
B
C
1
5
10
0
2
-3
4
9
6
3
2
14
9
8
THE PLAN:
A
B
C
+
=
HORST '18

Mutate

dplyr

```
mylego %>% filter(!is.na(pieces) & !is.na(US_retailPrice)) %>%
    mutate(Price_per_piece = US_retailPrice / pieces) %>% head(n = 3)
```

```
##   setID pieces     theme availability US_retailPrice minifigs Price_per_piece
## 1 26277    188 Education  Educational          94.95       NA       0.5050532
## 2 25949    280 Education  Educational         224.95       NA       0.8033929
## 3 25954      1 Education  Educational          14.95       NA      14.9500000
```

Base R

```
mylego2 <- mylego[!is.na(mylego$US_retailPrice) & !is.na(mylego$Price_per_piece),]
mylego2$Price_per_piece <- mylego2$Price_per_piece / mylego2$US_retailPrice
head(mylego2, n = 3)
```

```
## [1] setID           pieces          theme           availability
## [5] US_retailPrice  minifigs        Price_per_piece
## <0 rows> (or 0-length row.names)
```

Group By and Summarize


```
legosets %>% group_by(themeGroup) %>% summarize(mean_price = mean(US_retailPrice, na.rm = TRUE),
                                                sd_price = sd(US_retailPrice, na.rm = TRUE),
                                                median_price = median(US_retailPrice, na.rm = TRUE),
                                                n = n(),
                                                missing = sum(is.na(US_retailPrice)))
```

```
## # A tibble: 17 × 6
##    themeGroup       mean_price sd_price median_price     n missing
##    <chr>                 <dbl>    <dbl>        <dbl> <int>   <int>
##  1 Action/Adventure       40.2     38.9         30.0  1474     779
##  2 Art and crafts         34.9     47.7         17.5    97       9
##  3 Basic                  21.6     19.2         15.0   873     733
##  4 Constraction           16.4     12.4         13.0   502     284
##  5 Educational           182.     188.          130.    503     465
##  6 Girls                  35.8     24.0         23.0   240     227
##  7 Historical             34.2     32.4         20.0   473     400
##  8 Junior                 22.0     10.1         20.0   228     165
##  9 Licensed               53.3     71.7         30.0  2775    1066
## 10 Miscellaneous          20.7     29.2         13.0  6253    3961
## 11 Model making           74.3     92.1         40.0   771     384
## 12 Modern day             38.2     35.6         30.0  2469    1535
## 13 Pre-school             30.8     22.7         25.0  1562    1103
## 14 Racing                 26.8     26.5         15.0   270     176
```

Describe and Describe By

```
library(psych)
describe(legosets$US_retailPrice)
```

```
##    vars    n  mean   sd median trimmed   mad  min    max range skew kurtosis
## X1    1 7483 38.96 56.5  19.99    27.7 17.79 1.49 849.99 848.5 5.32    44.74
##      se
## X1 0.65
```

```
describeBy(legosets$US_retailPrice, group = legosets$availability, mat = TRUE, skew = FALSE)
```

```
##      item                group1 vars    n      mean        sd median   min    max range         se
## X11     1       {Not specified}    1 1831  26.84733  39.96747  19.99  1.49 789.99 788.5  0.9340335
## X12     2           Educational    1   12 212.86667 105.88283 222.45 14.95 399.95 385.0 30.5657410
## X13     3        LEGO exclusive    1 1039  57.21203 106.63125  12.99  1.99 849.99 848.0  3.3080857
## X14     4    LEGOLAND exclusive    1    2   4.99000   0.00000   4.99  4.99   4.99   0.0  0.0000000
## X15     5              Not sold    1    1  12.99000        NA  12.99 12.99  12.99   0.0         NA
## X16     6           Promotional    1    5   4.79000   0.83666   4.99  3.99   5.99   2.0  0.3741657
## X17     7 Promotional (Airline)    1    0       NaN        NA     NA   Inf   -Inf  -Inf         NA
## X18     8                Retail    1 4290  37.55889  38.44918  24.99  1.99 699.99 698.0  0.5870275
## X19     9      Retail - limited    1  302  63.54381  70.91908  39.99  2.49 449.99 447.5  4.0809343
## X110   10               Unknown    1    1   3.99000        NA   3.99  3.99   3.99   0.0         NA
```

Additional Resources

For data wrangling:

- `dplyr` website: https://dplyr.tidyverse.org
- R for Data Science book: https://r4ds.had.co.nz/wrangle-intro.html
- Wrangling penguins tutorial: https://allisonhorst.shinyapps.io/dplyr-learnr/#section-welcome
- Data transformation cheat sheet: https://github.com/rstudio/cheatsheets/raw/master/data-transformation.pdf

Grammer of Graphics

Data Visualizations with ggplot2

- `ggplot2` is an R package that provides an alternative framework based upon Wilkinson's (2005) Grammar of Graphics.
- `ggplot2` is, in general, more flexible for creating "prettier" and complex plots.
- Works by creating layers of different types of objects/geometries (i.e. bars, points, lines, polygons, etc.) `ggplot2` has at least three ways of creating plots:

    1. `qplot`
    2. `ggplot(...) + geom_XXX(...) + ...`
    3. `ggplot(...) + layer(...)`

- We will focus only on the second.

Parts of a `ggplot2` Statement

- Data

  ```
  ggplot(myDataFrame, aes(x=x, y=y))
  ```

- Layers

  ```
  geom_point(), geom_histogram()
  ```

- Facets

  ```
  facet_wrap(~ cut), facet_grid(~ cut)
  ```

- Scales

  ```
  scale_y_log10()
  ```

- Other options

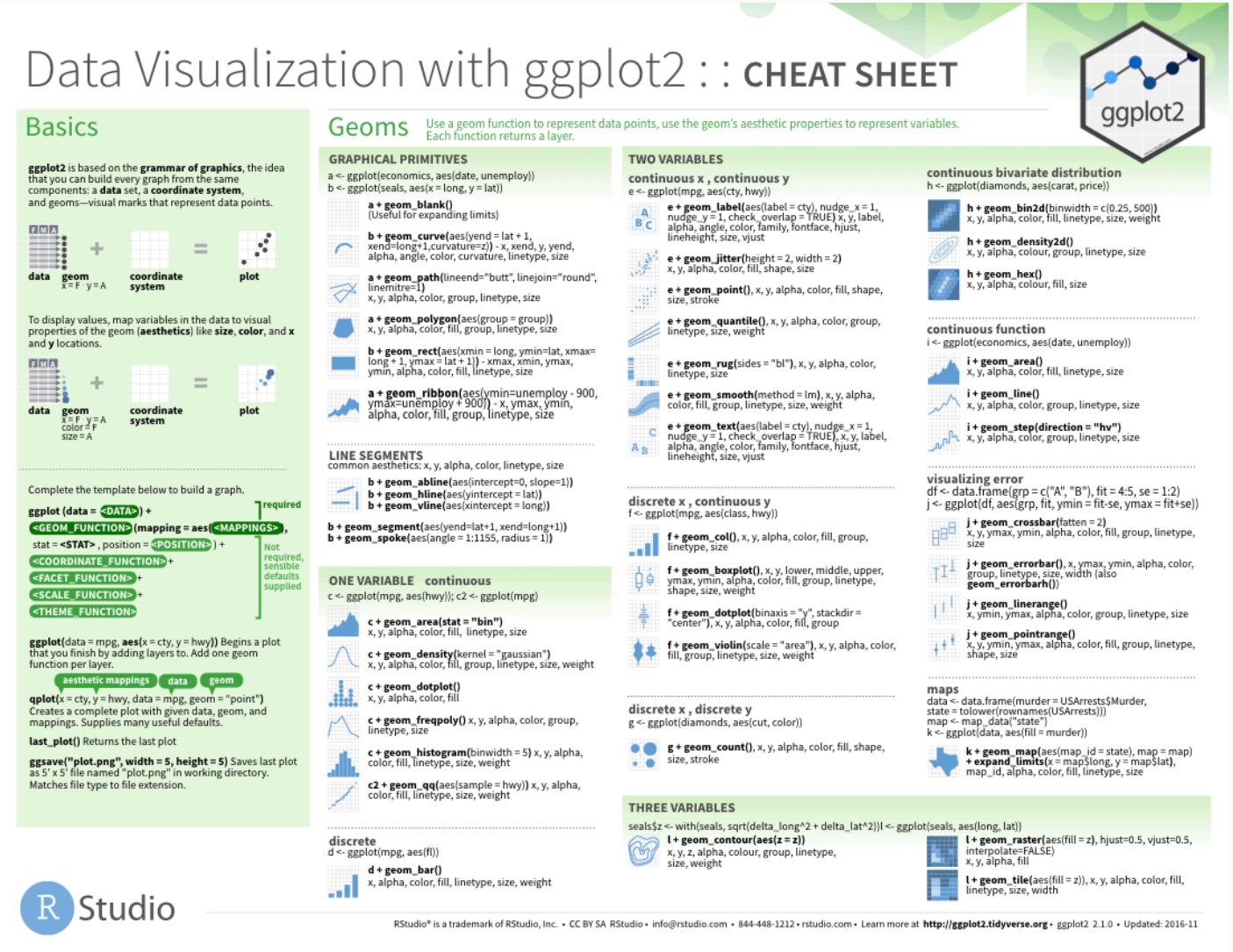
  ```
  ggtitle('my title'), ylim(c(0, 10000)), xlab('x-axis label')
  ```

Lots of geoms

```
ls('package:ggplot2')[grep('^geom_', ls('package:ggplot2'))]
```

```
##  [1] "geom_abline"           "geom_area"             "geom_bar"              "geom_bin_2d"
##  [5] "geom_bin2d"            "geom_blank"            "geom_boxplot"          "geom_col"
##  [9] "geom_contour"          "geom_contour_filled"   "geom_count"            "geom_crossbar"
## [13] "geom_curve"            "geom_density"          "geom_density_2d"       "geom_density_2d_filled"
## [17] "geom_density2d"        "geom_density2d_filled" "geom_dotplot"          "geom_errorbar"
## [21] "geom_errorbarh"        "geom_freqpoly"         "geom_function"         "geom_hex"
## [25] "geom_histogram"        "geom_hline"            "geom_jitter"           "geom_label"
## [29] "geom_line"             "geom_linerange"        "geom_map"              "geom_path"
## [33] "geom_point"            "geom_pointrange"       "geom_polygon"          "geom_qq"
## [37] "geom_qq_line"          "geom_quantile"         "geom_raster"           "geom_rect"
## [41] "geom_ribbon"           "geom_rug"              "geom_segment"          "geom_sf"
## [45] "geom_sf_label"         "geom_sf_text"          "geom_smooth"           "geom_spoke"
## [49] "geom_step"             "geom_text"             "geom_tile"             "geom_violin"
## [53] "geom_vline"
```

Data Visualization Cheat Sheet



Data Visualization with ggplot2 : : CHEAT SHEET

Basics

ggplot2 is based on the **grammar of graphics**, the idea that you can build every graph from the same components: a **data** set, a **coordinate system**, and geoms—visual marks that represent data points.

data | geom | coordinate system | plot

To display values, map variables in the data to visual properties of the geom (**aesthetics**) like **size**, **color**, and **x** and **y** locations.

data | geom (x = F, y = A, color = F, size = A) | coordinate system | plot

Complete the template below to build a graph.

```
ggplot (data = <DATA>) +                                  required
<GEOM_FUNCTION> (mapping = aes(<MAPPINGS>),
  stat = <STAT> , position = <POSITION> ) +               Not required, sensible defaults supplied
<COORDINATE_FUNCTION> +
<FACET_FUNCTION> +
<SCALE_FUNCTION> +
<THEME_FUNCTION>
```

ggplot(data = mpg, **aes**(x = cty, y = hwy)) Begins a plot that you finish by adding layers to. Add one geom function per layer.

aesthetic mappings | data | geom

qplot(x = cty, y = hwy, data = mpg, geom = "point") Creates a complete plot with given data, geom, and mappings. Supplies many useful defaults.

last_plot() Returns the last plot

ggsave("plot.png", width = 5, height = 5) Saves last plot as 5' x 5' file named "plot.png" in working directory. Matches file type to file extension.

Geoms

Use a geom function to represent data points, use the geom's aesthetic properties to represent variables. Each function returns a layer.

GRAPHICAL PRIMITIVES

a <- ggplot(economics, aes(date, unemploy))
b <- ggplot(seals, aes(x = long, y = lat))

a + geom_blank() (Useful for expanding limits)

b + geom_curve(aes(yend = lat + 1, xend=long+1,curvature=z)) - x, xend, y, yend, alpha, angle, color, curvature, linetype, size

a + geom_path(lineend="butt", linejoin="round", linemitre=1) x, y, alpha, color, group, linetype, size

a + geom_polygon(aes(group = group)) x, y, alpha, color, fill, group, linetype, size

b + geom_rect(aes(xmin = long, ymin=lat, xmax= long + 1, ymax = lat + 1)) - xmax, xmin, ymax, ymin, alpha, color, fill, linetype, size

a + geom_ribbon(aes(ymin=unemploy - 900, ymax=unemploy + 900)) - x, ymax, ymin, alpha, color, fill, group, linetype, size

LINE SEGMENTS

common aesthetics: x, y, alpha, color, linetype, size

b + geom_abline(aes(intercept=0, slope=1))
b + geom_hline(aes(yintercept = lat))
b + geom_vline(aes(xintercept = long))

b + geom_segment(aes(yend=lat+1, xend=long+1))
b + geom_spoke(aes(angle = 1:1155, radius = 1))

ONE VARIABLE continuous

c <- ggplot(mpg, aes(hwy)); c2 <- ggplot(mpg)

c + geom_area(stat = "bin") x, y, alpha, color, fill, linetype, size

c + geom_density(kernel = "gaussian") x, y, alpha, color, fill, group, linetype, size, weight

c + geom_dotplot() x, y, alpha, color, fill

c + geom_freqpoly() x, y, alpha, color, group, linetype, size

c + geom_histogram(binwidth = 5) x, y, alpha, color, fill, linetype, size, weight

c2 + geom_qq(aes(sample = hwy)) x, y, alpha, color, fill, linetype, size, weight

discrete

d <- ggplot(mpg, aes(fl))

d + geom_bar() x, alpha, color, fill, linetype, size, weight

TWO VARIABLES

continuous x , continuous y

e <- ggplot(mpg, aes(cty, hwy))

e + geom_label(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE) x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

e + geom_jitter(height = 2, width = 2) x, y, alpha, color, fill, shape, size

e + geom_point(), x, y, alpha, color, fill, shape, size, stroke

e + geom_quantile(), x, y, alpha, color, group, linetype, size, weight

e + geom_rug(sides = "bl"), x, y, alpha, color, linetype, size

e + geom_smooth(method = lm), x, y, alpha, color, fill, group, linetype, size, weight

e + geom_text(aes(label = cty), nudge_x = 1, nudge_y = 1, check_overlap = TRUE), x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

discrete x , continuous y

f <- ggplot(mpg, aes(class, hwy))

f + geom_col(), x, y, alpha, color, fill, group, linetype, size

f + geom_boxplot(), x, y, lower, middle, upper, ymax, ymin, alpha, color, fill, group, linetype, shape, size, weight

f + geom_dotplot(binaxis = "y", stackdir = "center"), x, y, alpha, color, fill, group

f + geom_violin(scale = "area"), x, y, alpha, color, fill, group, linetype, size, weight

discrete x , discrete y

g <- ggplot(diamonds, aes(cut, color))

g + geom_count(), x, y, alpha, color, fill, shape, size, stroke

continuous bivariate distribution

h <- ggplot(diamonds, aes(carat, price))

h + geom_bin2d(binwidth = c(0.25, 500)) x, y, alpha, color, fill, linetype, size, weight

h + geom_density2d() x, y, alpha, colour, group, linetype, size

h + geom_hex() x, y, alpha, colour, fill, size

continuous function

i <- ggplot(economics, aes(date, unemploy))

i + geom_area() x, y, alpha, color, fill, linetype, size

i + geom_line() x, y, alpha, color, group, linetype, size

i + geom_step(direction = "hv") x, y, alpha, color, group, linetype, size

visualizing error

df <- data.frame(grp = c("A", "B"), fit = 4:5, se = 1:2)
j <- ggplot(df, aes(grp, fit, ymin = fit-se, ymax = fit+se))

j + geom_crossbar(fatten = 2) x, y, ymax, ymin, alpha, color, fill, group, linetype, size

j + geom_errorbar(), x, ymax, ymin, alpha, color, group, linetype, size, width (also **geom_errorbarh()**)

j + geom_linerange() x, ymin, ymax, alpha, color, group, linetype, size

j + geom_pointrange() x, y, ymin, ymax, alpha, color, fill, group, linetype, shape, size

maps

data <- data.frame(murder = USArrests$Murder, state = tolower(rownames(USArrests)))
map <- map_data("state")
k <- ggplot(data, aes(fill = murder))

k + geom_map(aes(map_id = state), map = map) **+ expand_limits**(x = map$long, y = map$lat), map_id, alpha, color, fill, linetype, size

THREE VARIABLES

seals$z <- with(seals, sqrt(delta_long^2 + delta_lat^2))l <- ggplot(seals, aes(long, lat))

l + geom_contour(aes(z = z)) x, y, z, alpha, colour, group, linetype, size, weight

l + geom_raster(aes(fill = z), hjust=0.5, vjust=0.5, interpolate=FALSE) x, y, alpha, fill

l + geom_tile(aes(fill = z)), x, y, alpha, color, fill, linetype, size, width

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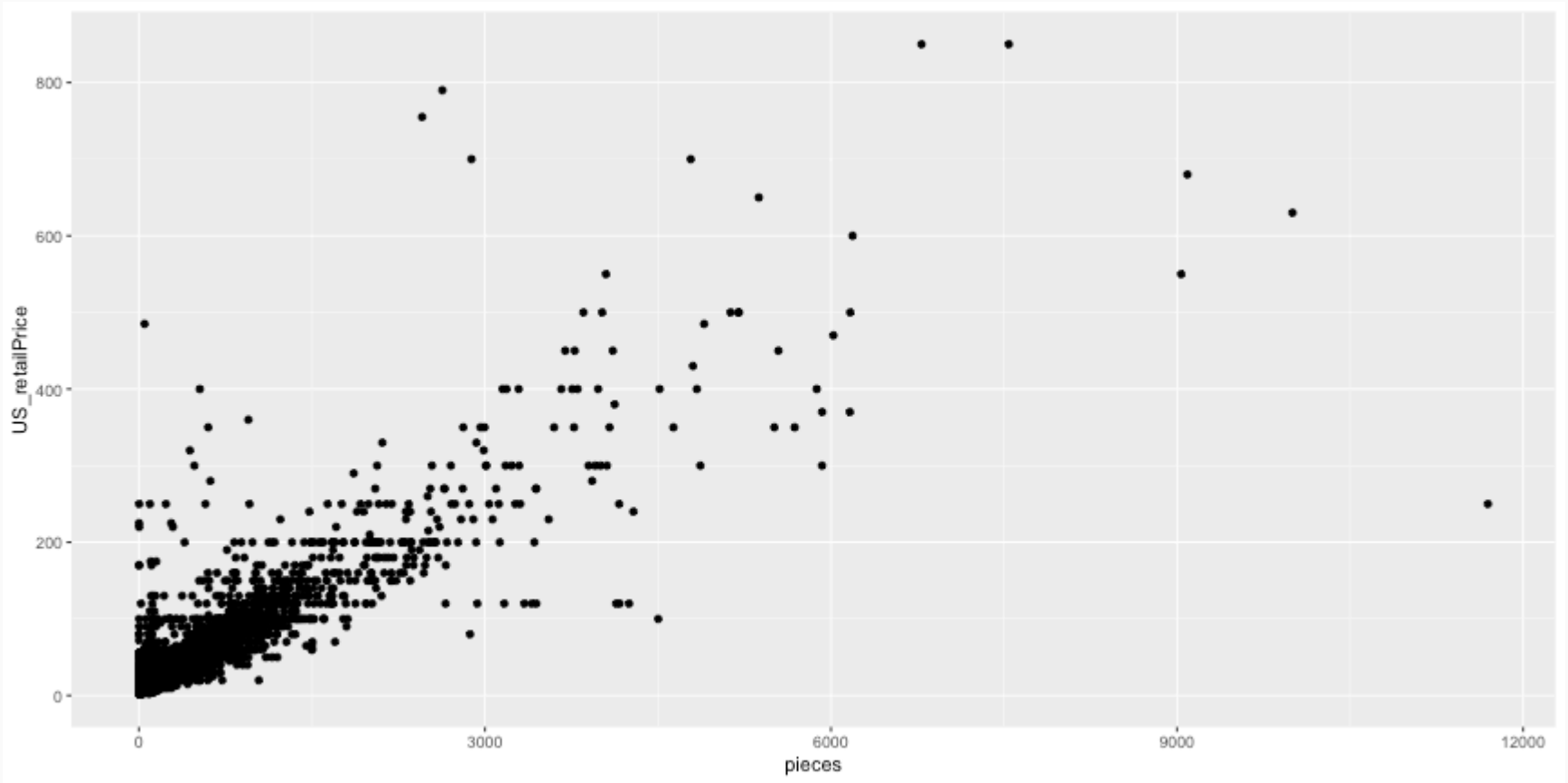
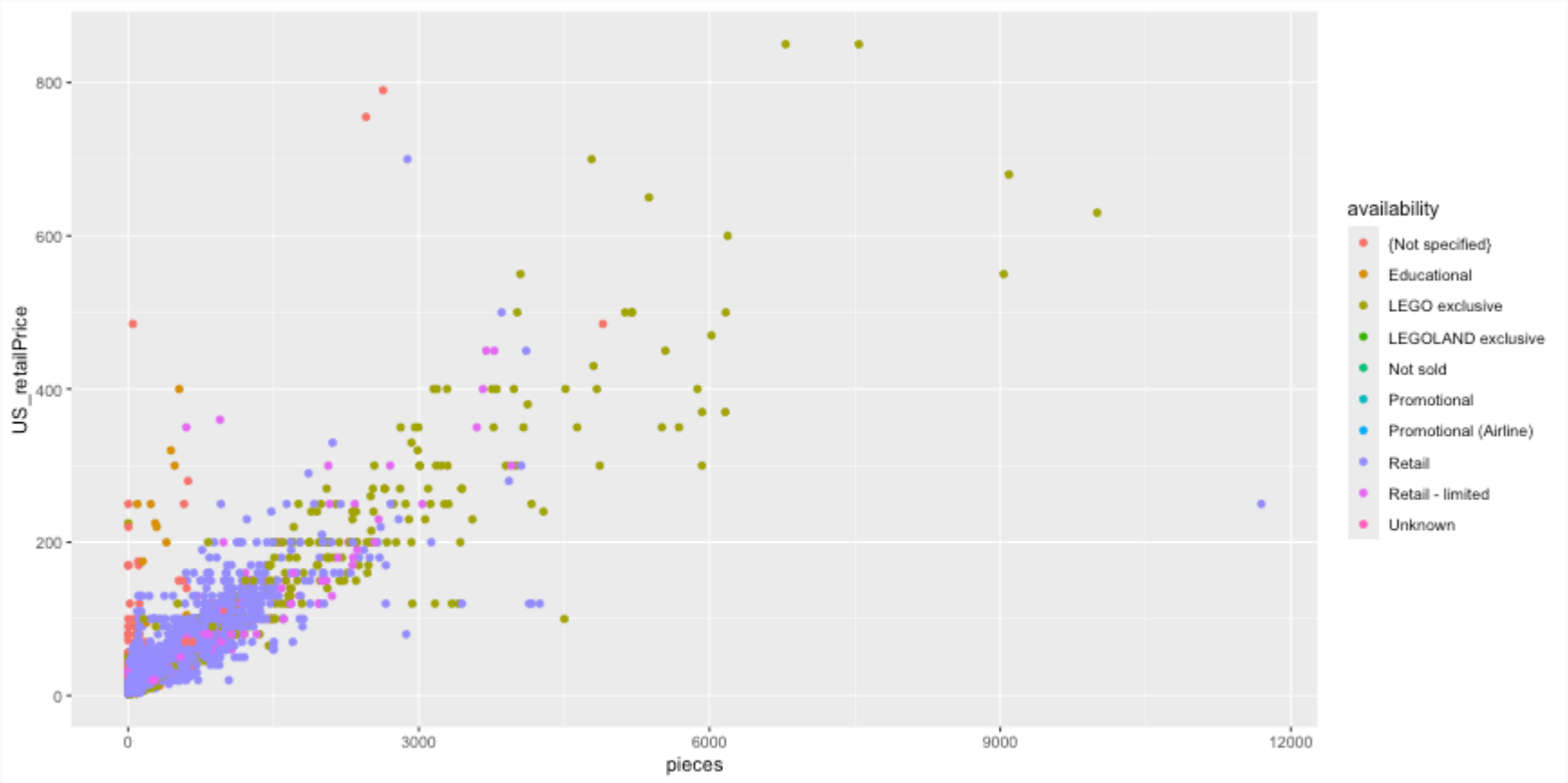
Scatterplot

```
ggplot(legosets, aes(x=pieces, y=US_retailPrice)) + geom_point()
```



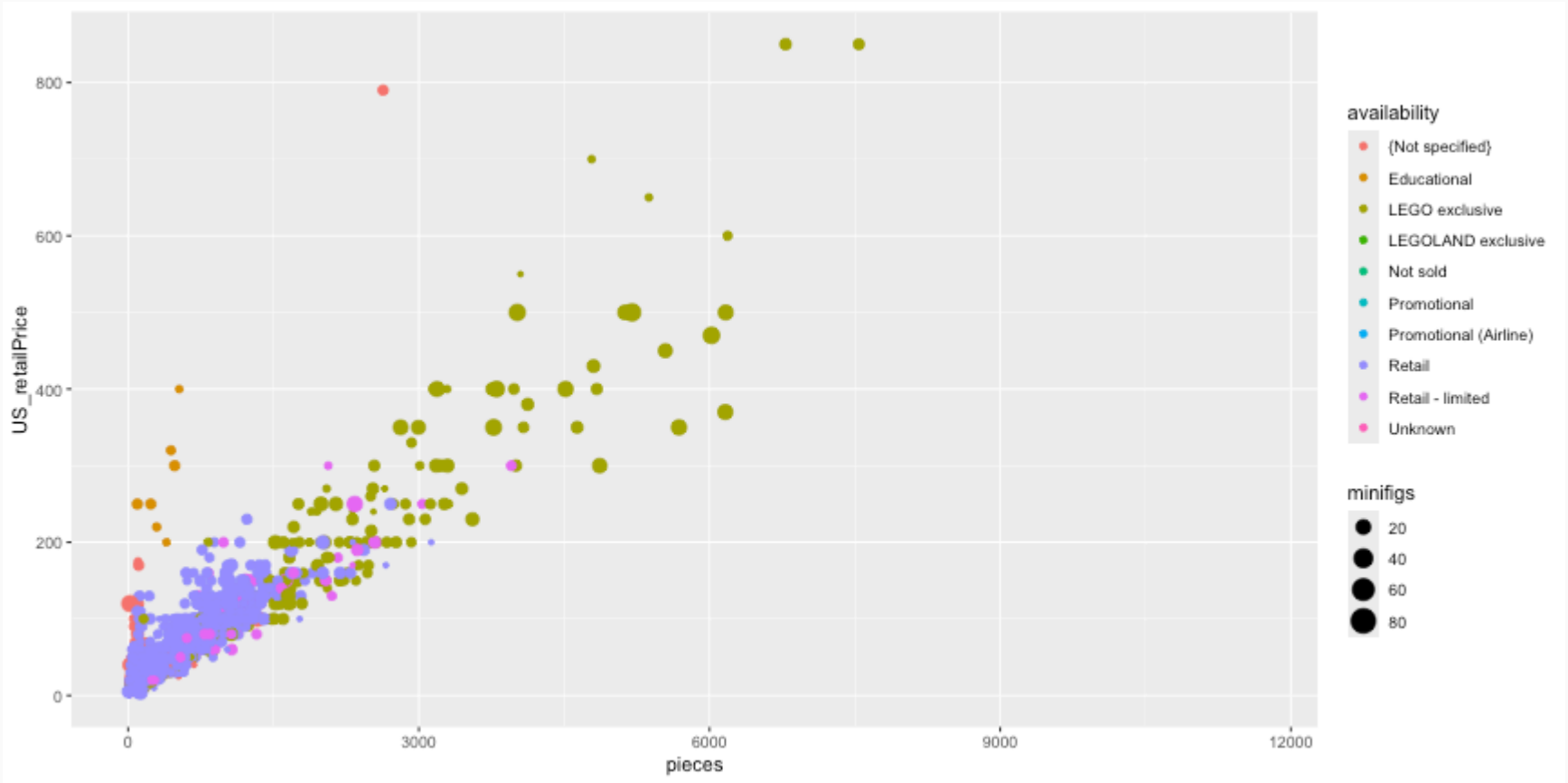
Scatterplot (cont.)

```
ggplot(legosets, aes(x=pieces, y=US_retailPrice, color=availability)) + geom_point()
```



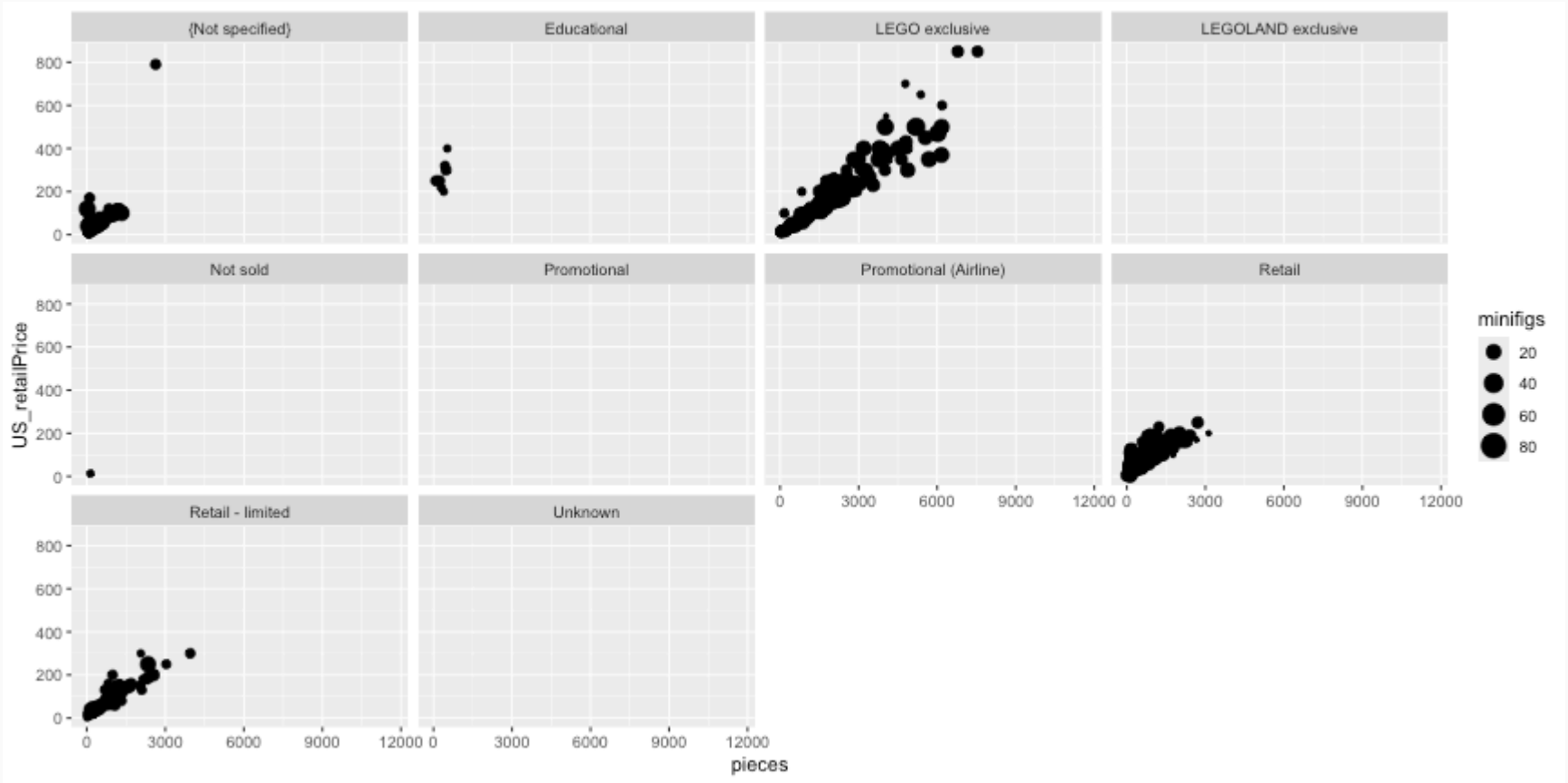
Scatterplot (cont.)

```
ggplot(legosets, aes(x=pieces, y=US_retailPrice, size=minifigs, color=availability)) + geom_point()
```



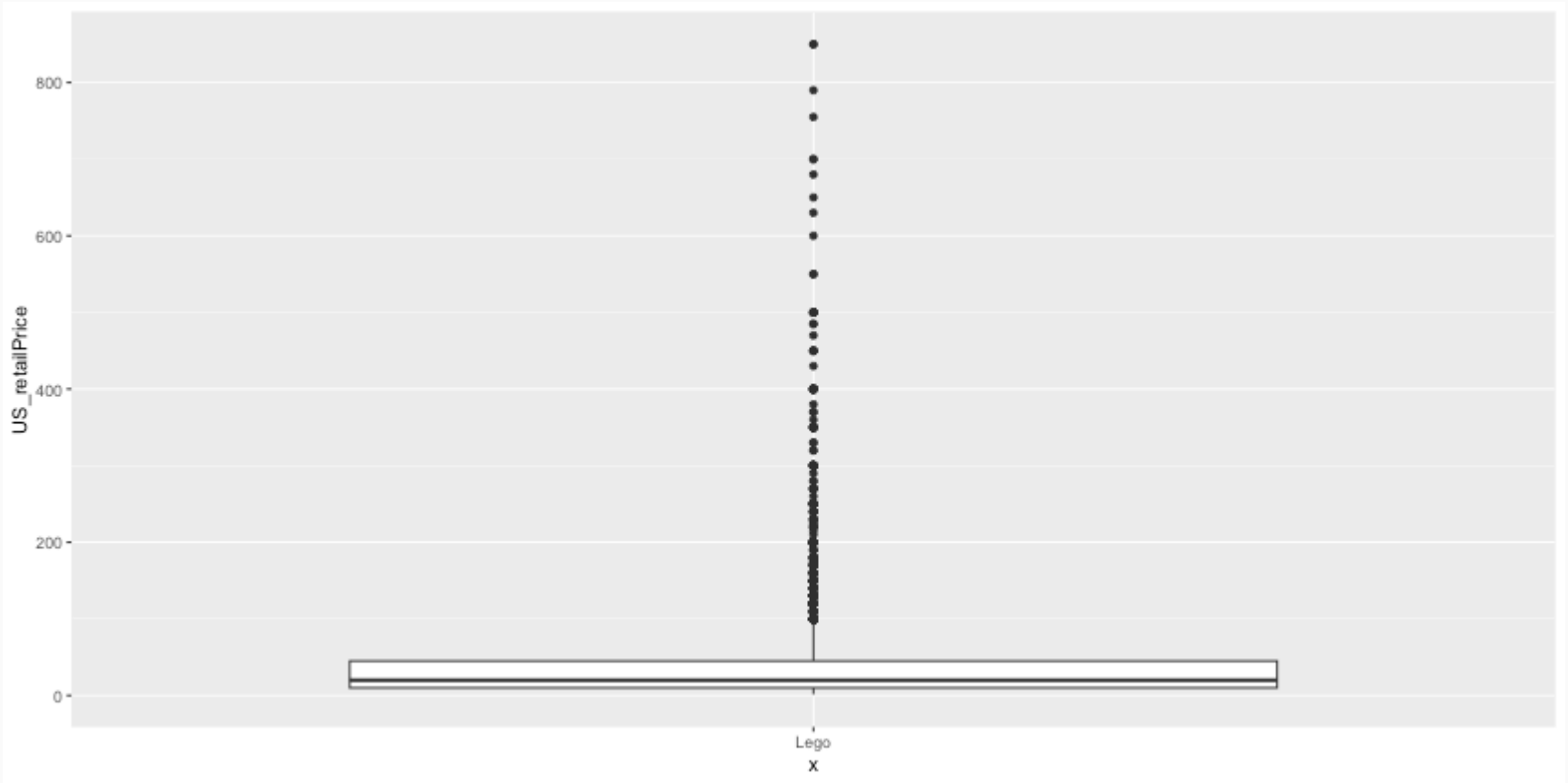
Scatterplot (cont.)

```
ggplot(legosets, aes(x=pieces, y=US_retailPrice, size=minifigs)) + geom_point() + facet_wrap(~ availability)
```



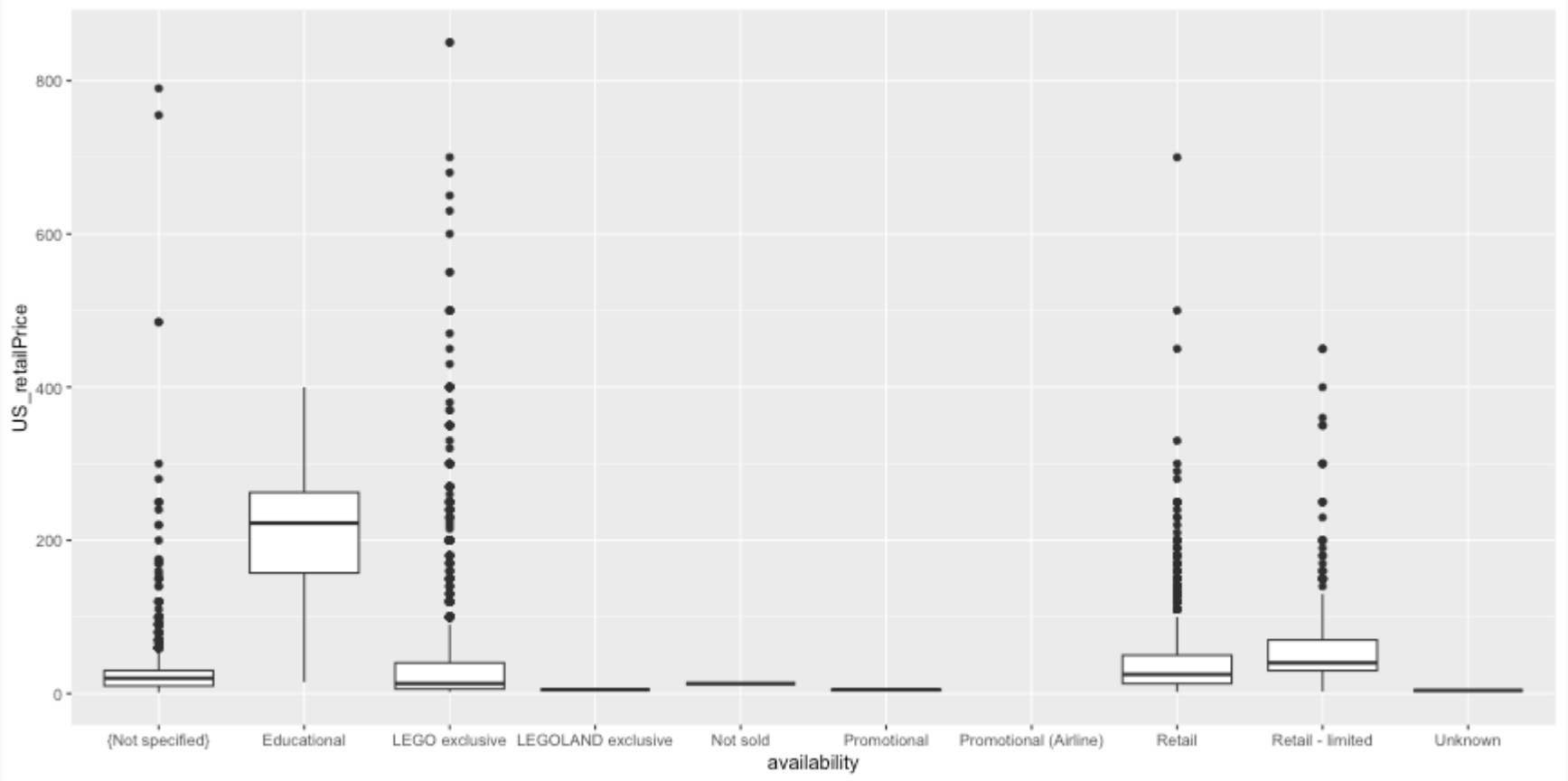
Boxplots

```
ggplot(legosets, aes(x='Lego', y=US_retailPrice)) + geom_boxplot()
```



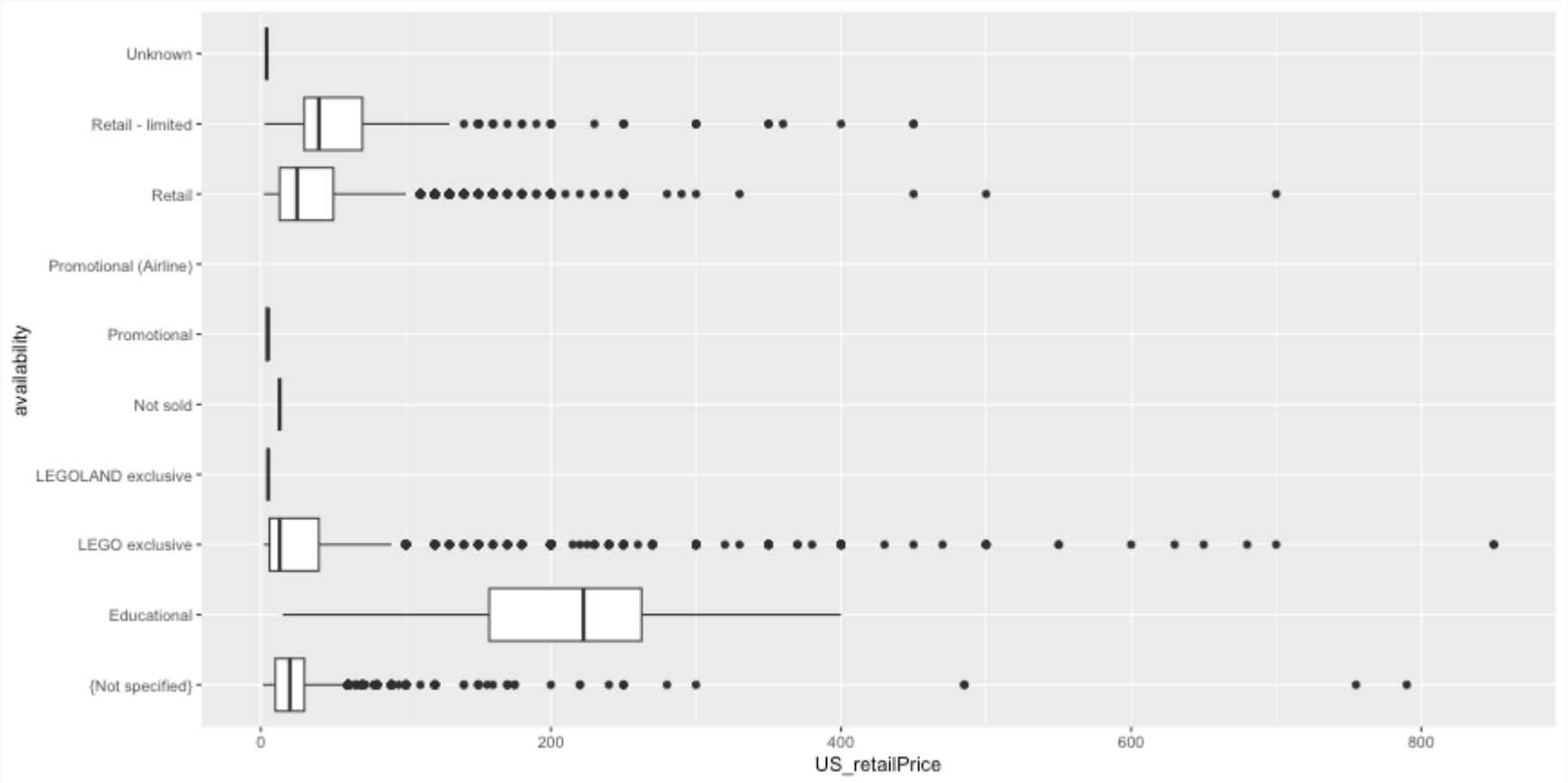
Boxplots (cont.)

```
ggplot(legosets, aes(x=availability, y=US_retailPrice)) + geom_boxplot()
```



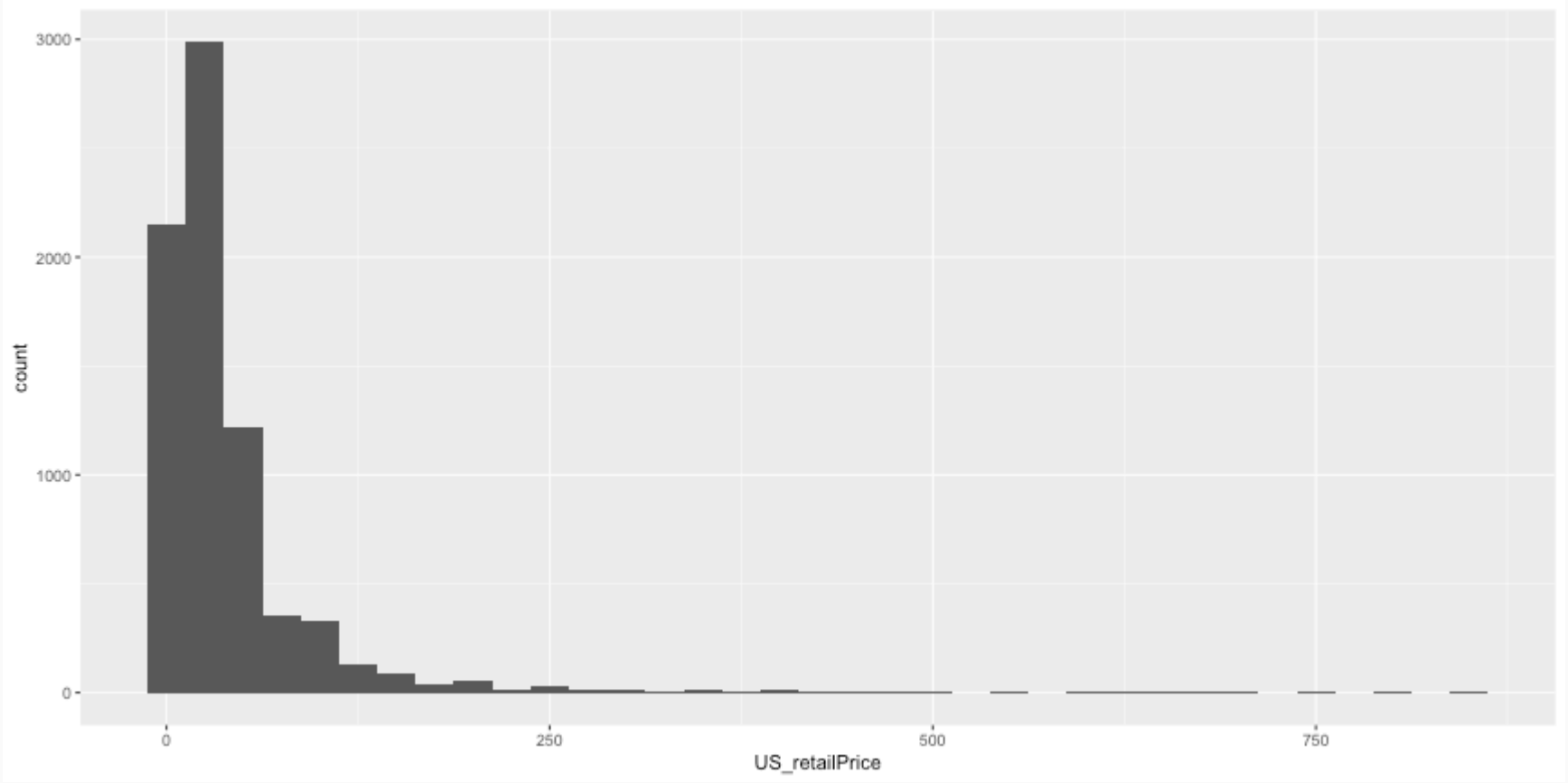
Boxplot (cont.)

```
ggplot(legosets, aes(x=availability, y=US_retailPrice)) + geom_boxplot() + coord_flip()
```



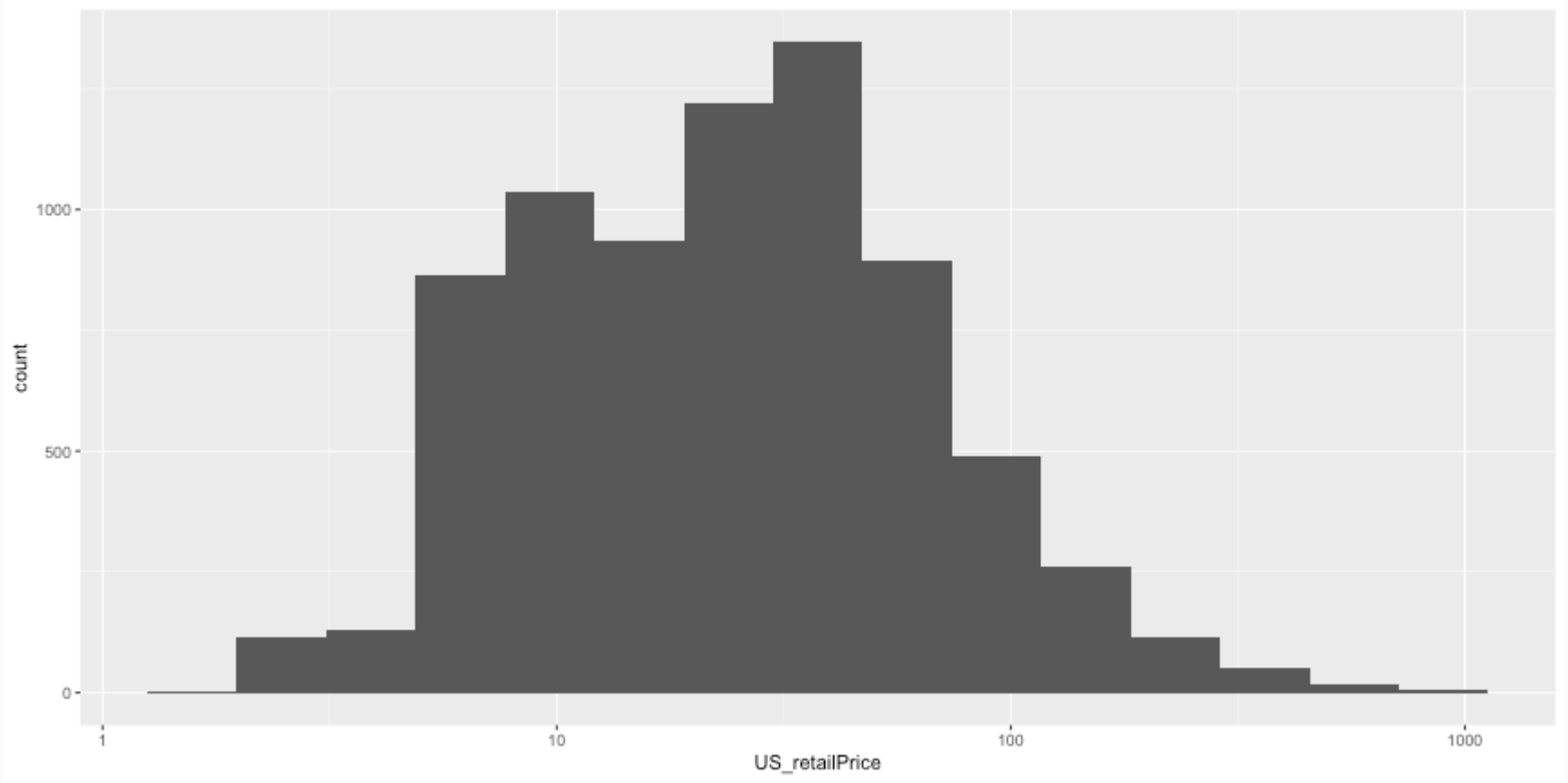
Histograms

```
ggplot(legosets, aes(x = US_retailPrice)) + geom_histogram(binwidth = 25)
```



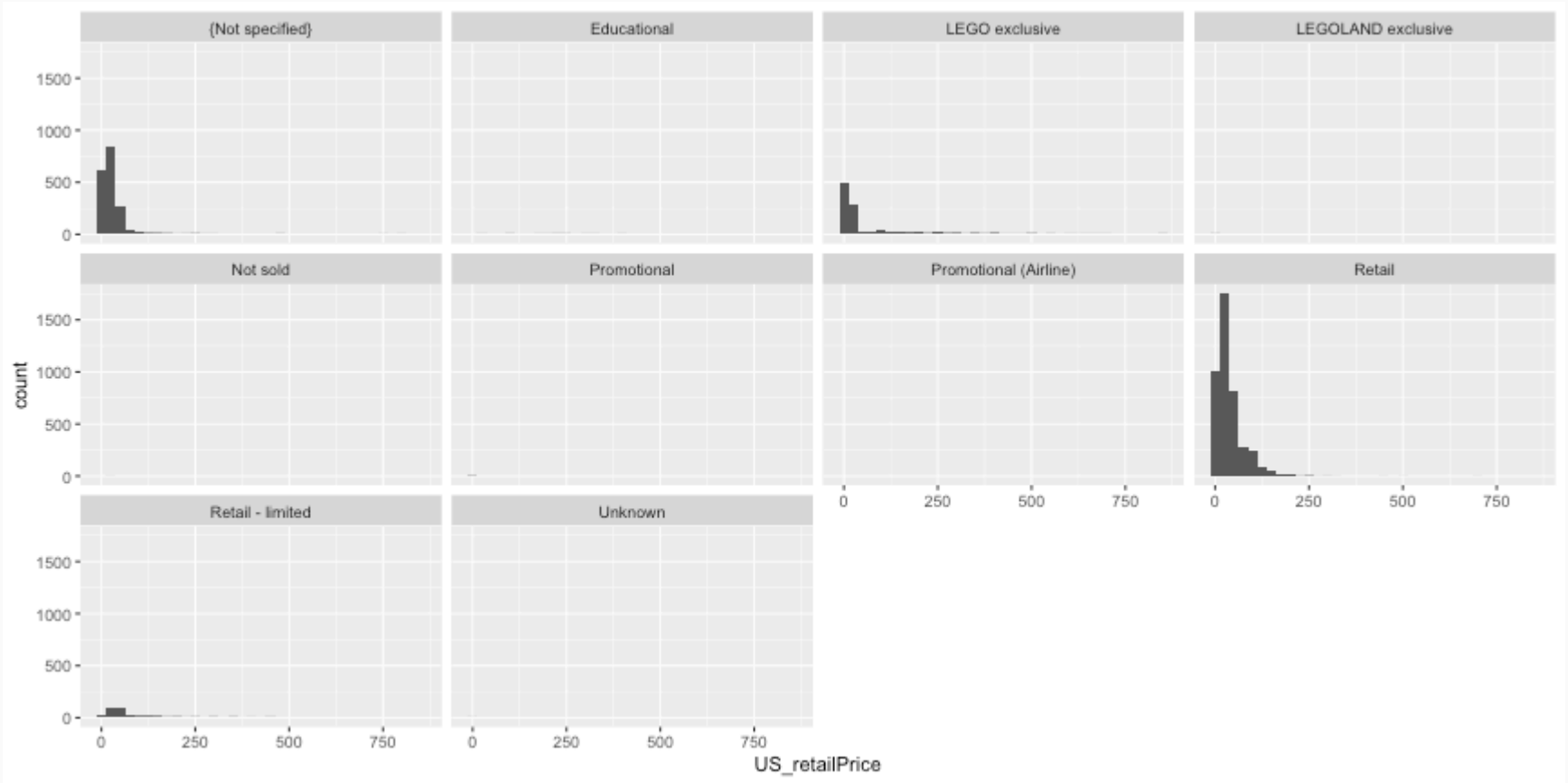
Histograms (cont.)

```
ggplot(legosets, aes(x = US_retailPrice)) + geom_histogram(bins = 15) + scale_x_log10()
```



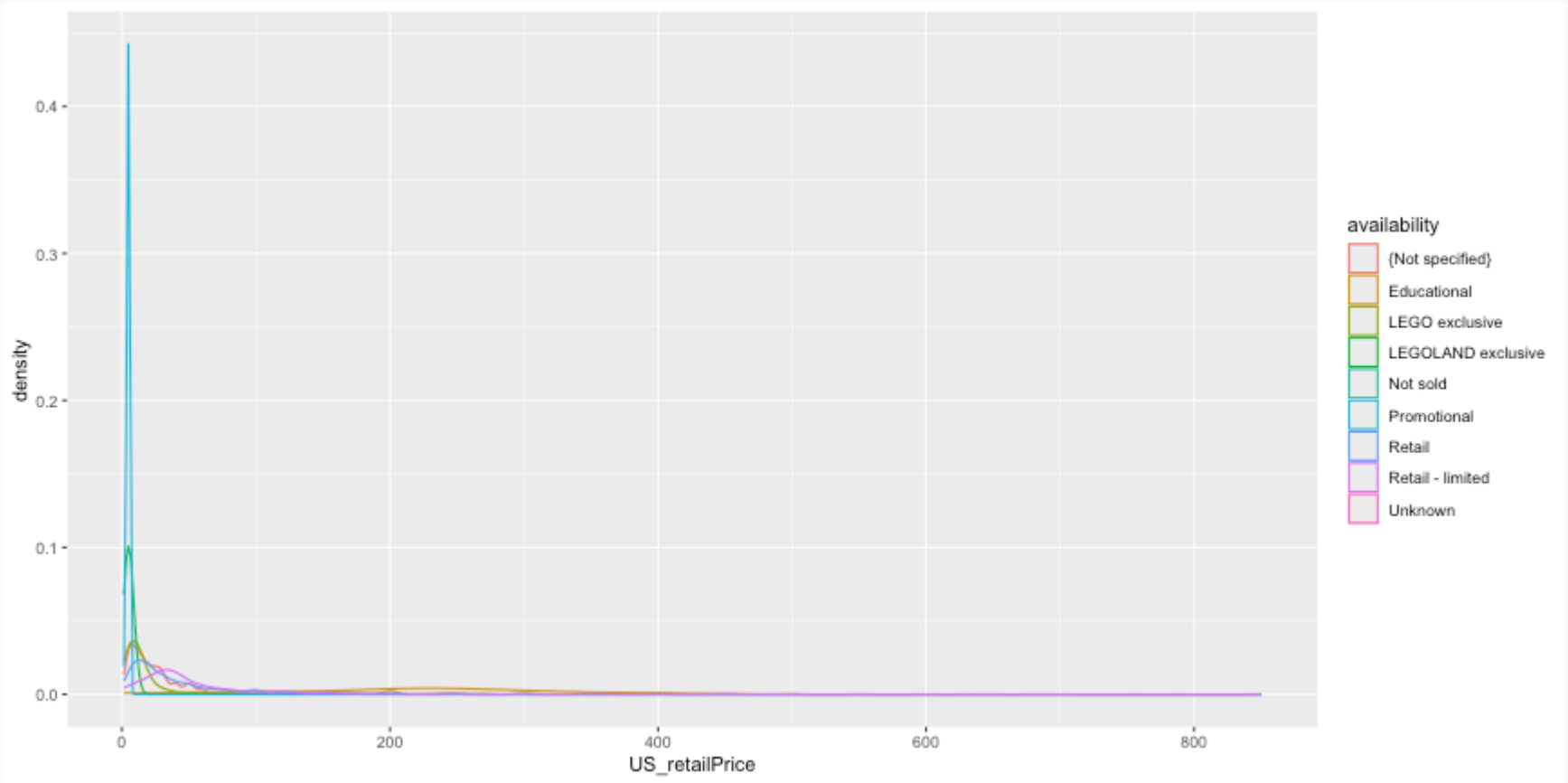
Histograms (cont.)

```
ggplot(legosets, aes(x = US_retailPrice)) + geom_histogram(binwidth = 25) + facet_wrap(~ availability)
```



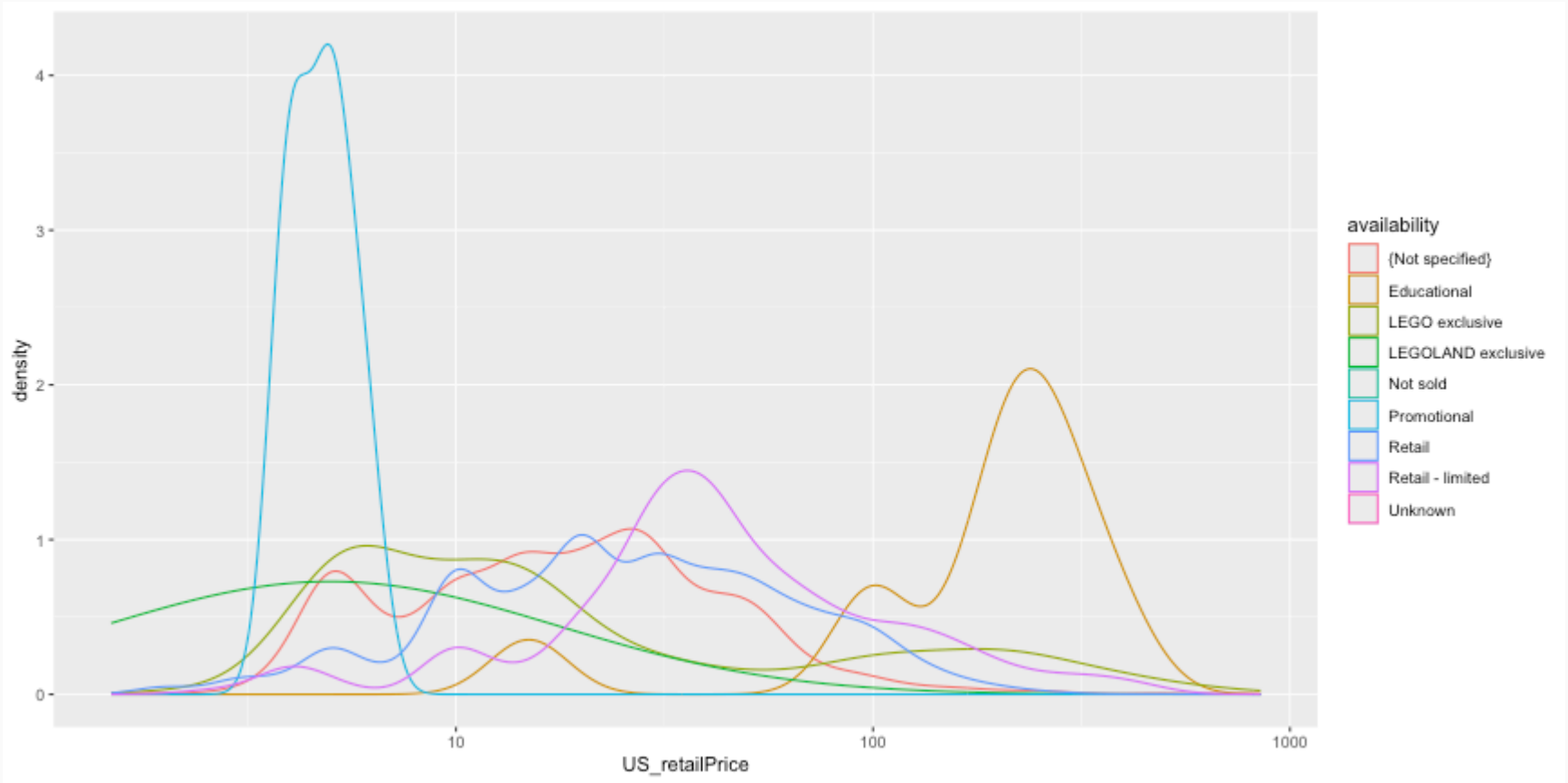
Density Plots

```
ggplot(legosets, aes(x = US_retailPrice, color = availability)) + geom_density()
```

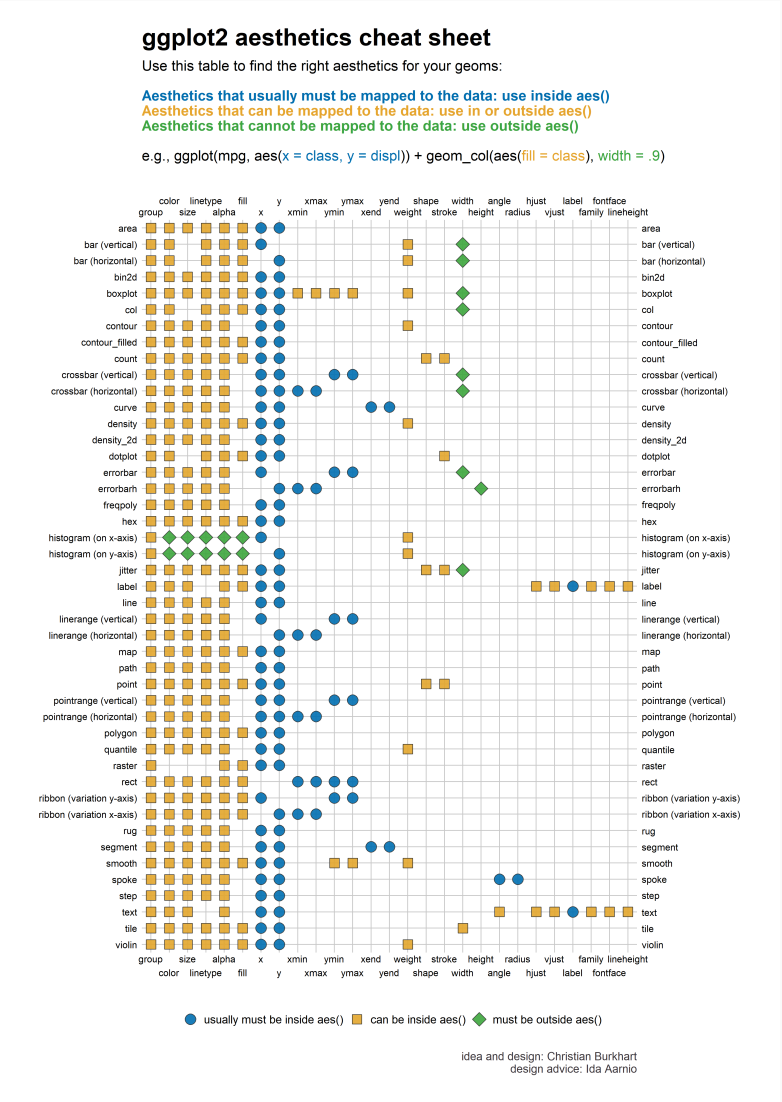


Density Plots (cont.)

```
ggplot(legosets, aes(x = US_retailPrice, color = availability)) + geom_density() + scale_x_log10()
```



ggplot2 aesthetics



Likert Scales

Likert scales are a type of questionnaire where respondents are asked to rate items on scales usually ranging from four to seven levels (e.g. strongly disagree to strongly agree).

```
library(likert)
library(reshape)
data(pisaitems)
items24 <- pisaitems[,substr(names(pisaitems), 1,5) == 'ST24Q']
items24 <- rename(items24, c(
            ST24Q01="I read only if I have to.",
            ST24Q02="Reading is one of my favorite hobbies.",
            ST24Q03="I like talking about books with other people.",
            ST24Q04="I find it hard to finish books.",
            ST24Q05="I feel happy if I receive a book as a present.",
            ST24Q06="For me, reading is a waste of time.",
            ST24Q07="I enjoy going to a bookstore or a library.",
            ST24Q08="I read only to get information that I need.",
            ST24Q09="I cannot sit still and read for more than a few minutes.",
            ST24Q10="I like to express my opinions about books I have read.",
            ST24Q11="I like to exchange books with my friends."))
```

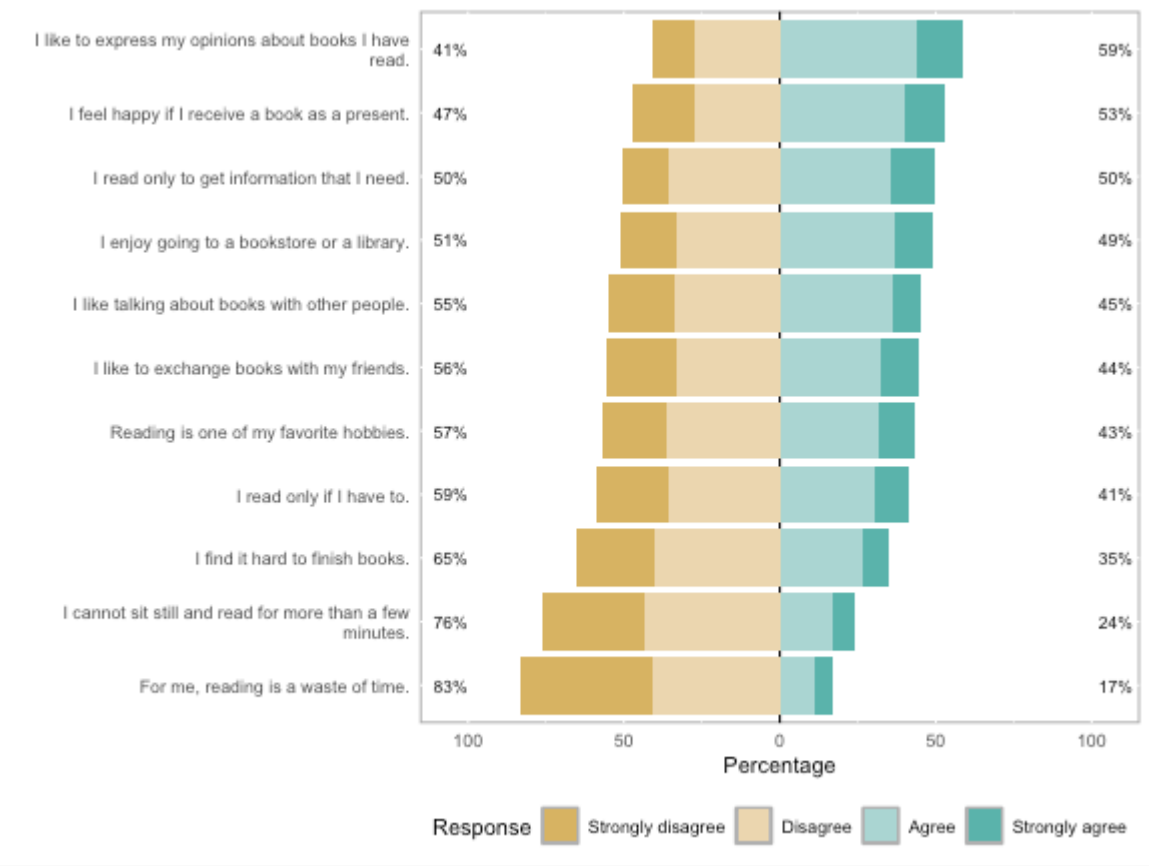
likert R Package

```
l24 <- likert(items24)
summary(l24)
```

```
##                                                      Item      low neutral     high     mean        sd
## 10   I like to express my opinions about books I have read. 41.07516       0 58.92484 2.604913 0.9009968
## 5            I feel happy if I receive a book as a present. 46.93475       0 53.06525 2.466751 0.9446590
## 8               I read only to get information that I need. 50.39874       0 49.60126 2.484616 0.9089688
## 7                I enjoy going to a bookstore or a library. 51.21231       0 48.78769 2.428508 0.9164136
## 3             I like talking about books with other people. 54.99129       0 45.00871 2.328049 0.9090326
## 11               I like to exchange books with my friends. 55.54115       0 44.45885 2.343193 0.9609234
## 2                   Reading is one of my favorite hobbies. 56.64470       0 43.35530 2.344530 0.9277495
## 1                                I read only if I have to. 58.72868       0 41.27132 2.291811 0.9369023
## 4                          I find it hard to finish books. 65.35125       0 34.64875 2.178299 0.8991628
## 9  I cannot sit still and read for more than a few minutes. 76.24524       0 23.75476 1.974736 0.8793028
## 6                       For me, reading is a waste of time. 82.88729       0 17.11271 1.810093 0.8611554
```

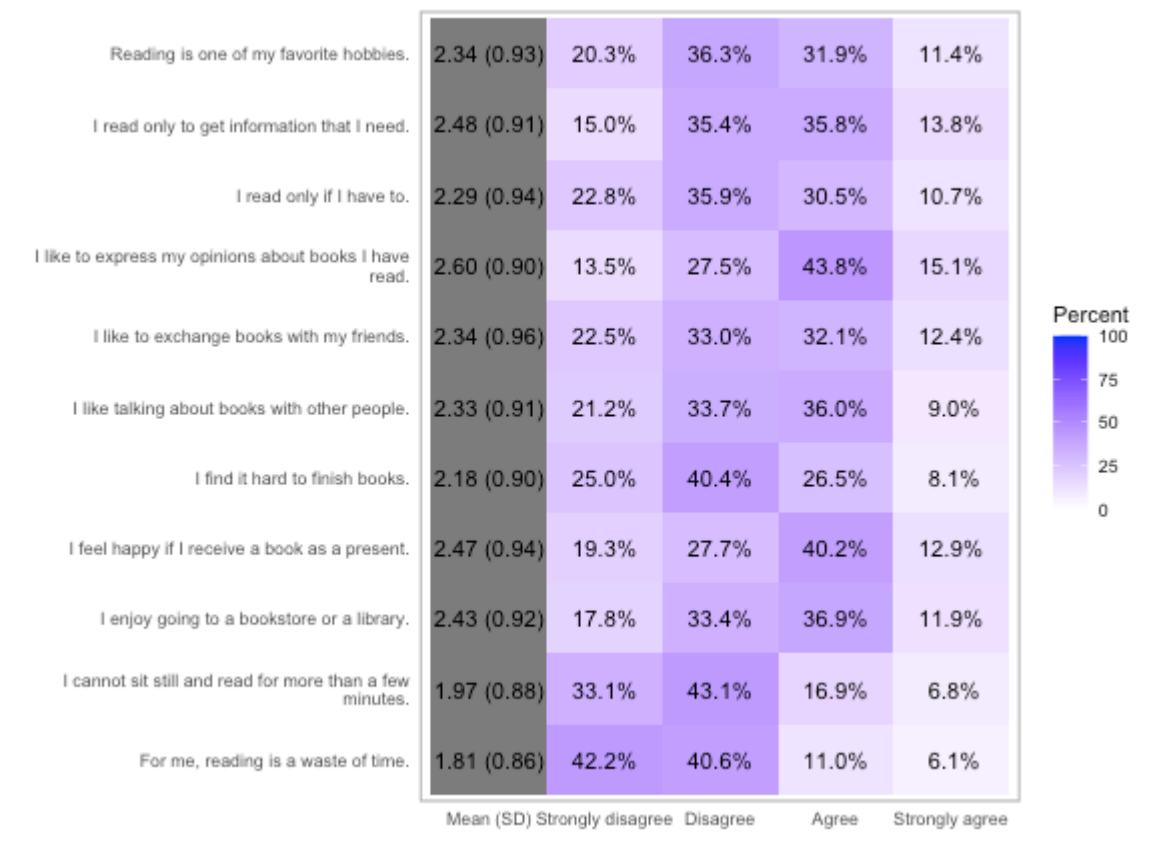
likert Plots

```
plot(l24)
```



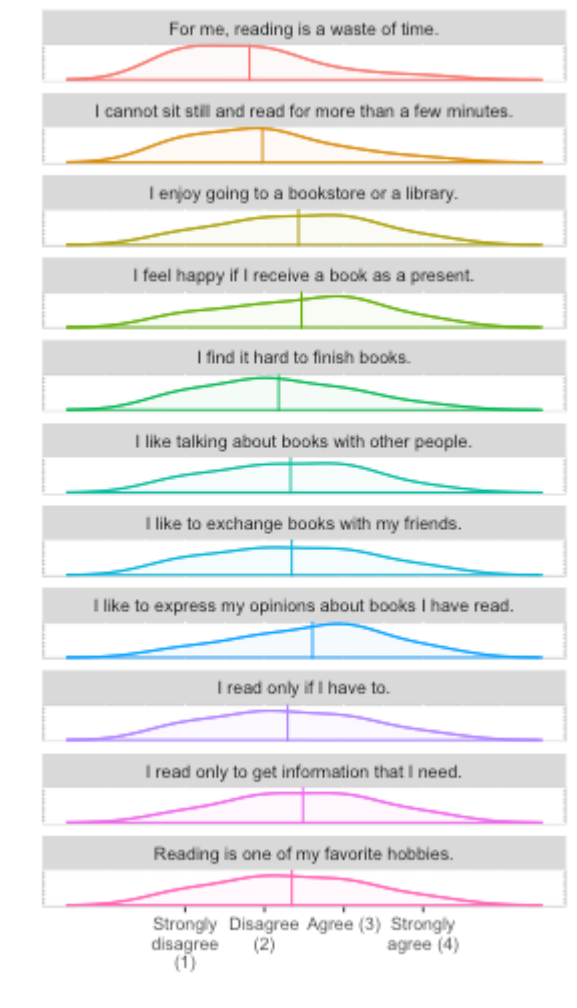
likert Plots

```
plot(l24, type='heat')
```



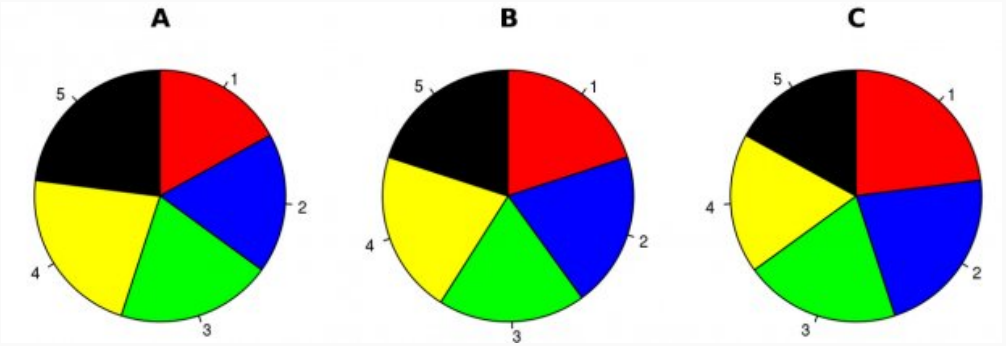
likert Plots

```
plot(l24, type='density')
```



Pie Charts

There is only one pie chart in *OpenIntro Statistics* (Diez, Barr, & Çetinkaya-Rundel, 2015, p. 48). Consider the following three pie charts that represent the preference of five different colors. Is there a difference between the three pie charts? This is probably a difficult to answer.



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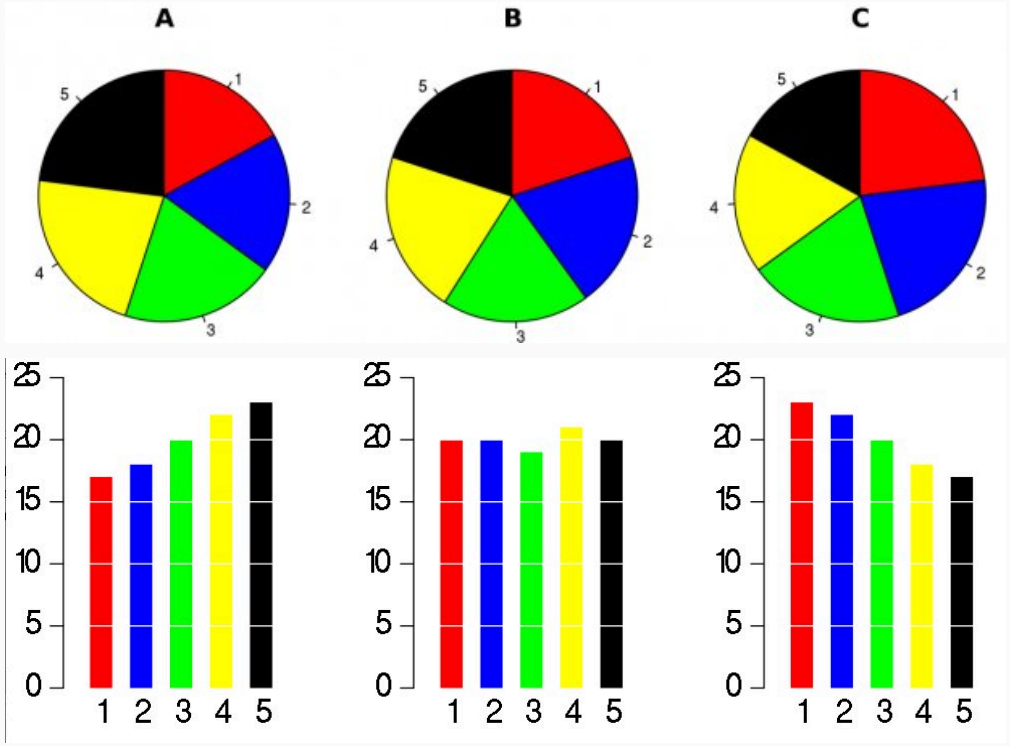

Source: https://en.wikipedia.org/wiki/Pie_chart.

"There is no data that can be displayed in a pie chart that cannot better be displayed in some other type of chart"

John Tukey

Additional Resources

For data wrangling:

- `dplyr` website: https://dplyr.tidyverse.org
- R for Data Science book: https://r4ds.had.co.nz/wrangle-intro.html
- Wrangling penguins tutorial: https://allisonhorst.shinyapps.io/dplyr-learnr/#section-welcome
- Data transformation cheat sheet: https://github.com/rstudio/cheatsheets/raw/master/data-transformation.pdf

For data visualization:

- `ggplot2` website: https://ggplot2.tidyverse.org
- R for Data Science book: https://r4ds.had.co.nz/data-visualisation.html
- R Graphics Cookbook: https://r-graphics.org
- Data visualization cheat sheet: https://github.com/rstudio/cheatsheets/raw/master/data-visualization-2.1.pdf

One Minute Paper

1. What was the most important thing you learned during this class?
2. What important question remains unanswered for you?

https://forms.gle/U4UXAosdjHorxY919