Data visualization with ggplot2

IS381 - Statistics & Probability for Data Analytics

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One Minute Paper Results

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

```
## NULL
```

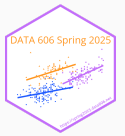
What important question remains unanswered for you?

```
## NULL
```

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

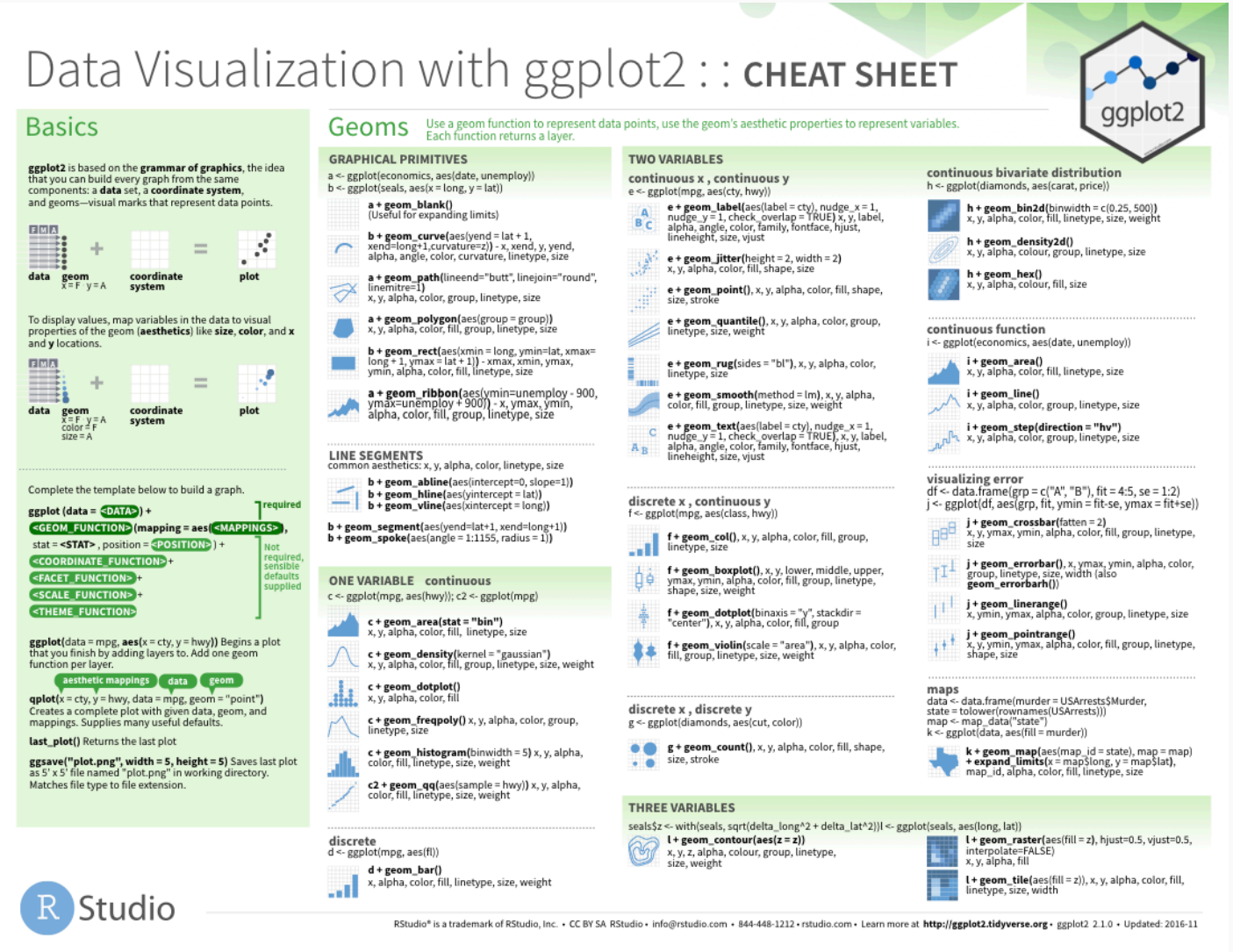
  ```
  ggtitle('my title'), ylim(c(0, 10000)), xlab('x-axis label')
  ```

Lots of geoms

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

```
##  [1] "geom_abline"           "geom_area"             "geom_bar"
##  [4] "geom_bin_2d"           "geom_bin2d"            "geom_blank"
##  [7] "geom_boxplot"          "geom_col"              "geom_contour"
## [10] "geom_contour_filled"   "geom_count"            "geom_crossbar"
## [13] "geom_curve"            "geom_density"          "geom_density_2d"
## [16] "geom_density_2d_filled" "geom_density2d"       "geom_density2d_filled"
## [19] "geom_dotplot"          "geom_errorbar"         "geom_errorbarh"
## [22] "geom_freqpoly"         "geom_function"         "geom_hex"
## [25] "geom_histogram"        "geom_hline"            "geom_jitter"
## [28] "geom_label"            "geom_line"             "geom_linerange"
## [31] "geom_map"              "geom_path"             "geom_point"
## [34] "geom_pointrange"       "geom_polygon"          "geom_qq"
## [37] "geom_qq_line"          "geom_quantile"         "geom_raster"
## [40] "geom_rect"             "geom_ribbon"           "geom_rug"
## [43] "geom_segment"          "geom_sf"               "geom_sf_label"
## [46] "geom_sf_text"          "geom_smooth"           "geom_spoke"
## [49] "geom_step"             "geom_text"             "geom_tile"
## [52] "geom_violin"           "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 x = F y = A | 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

RStudio

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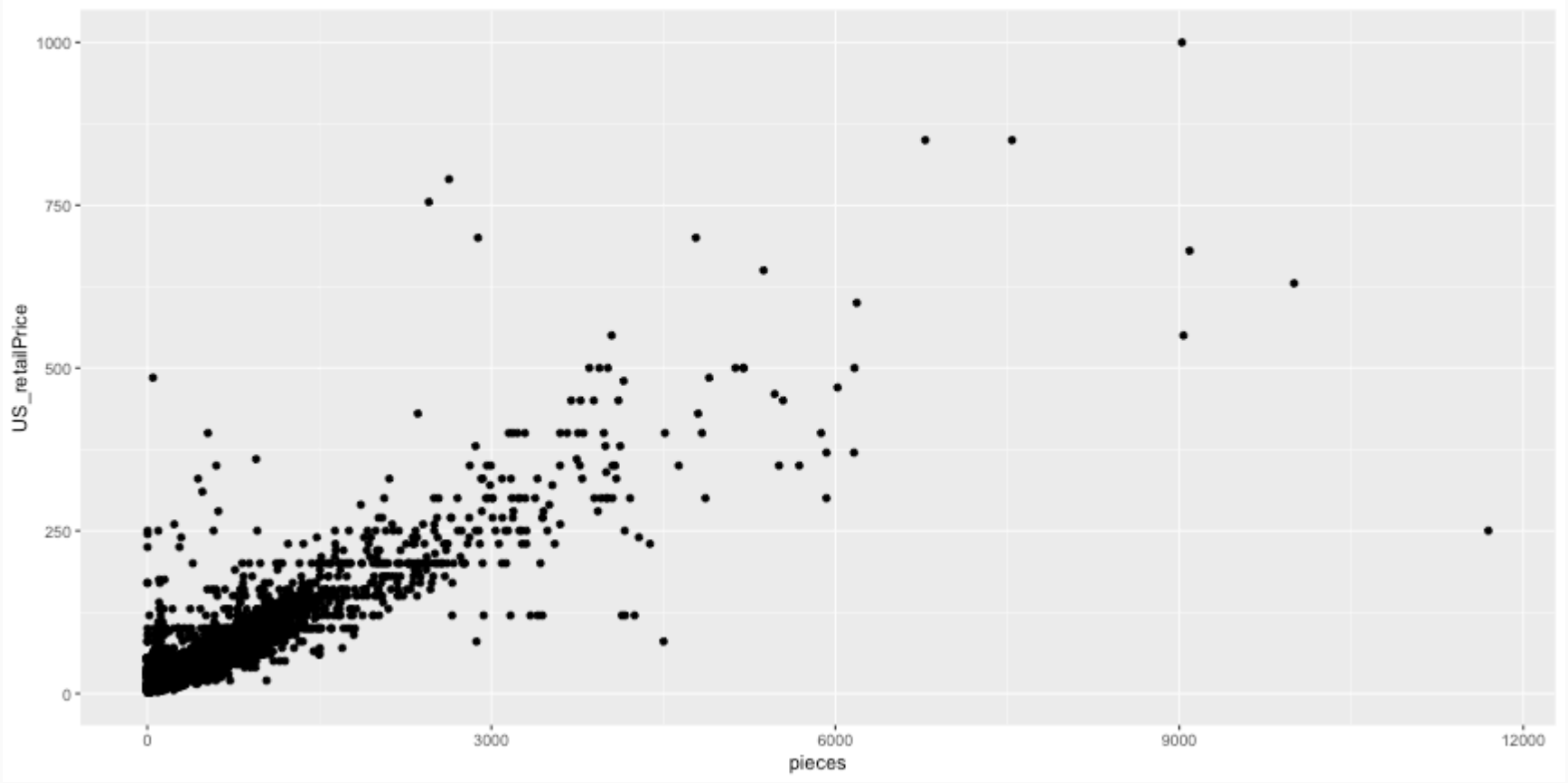
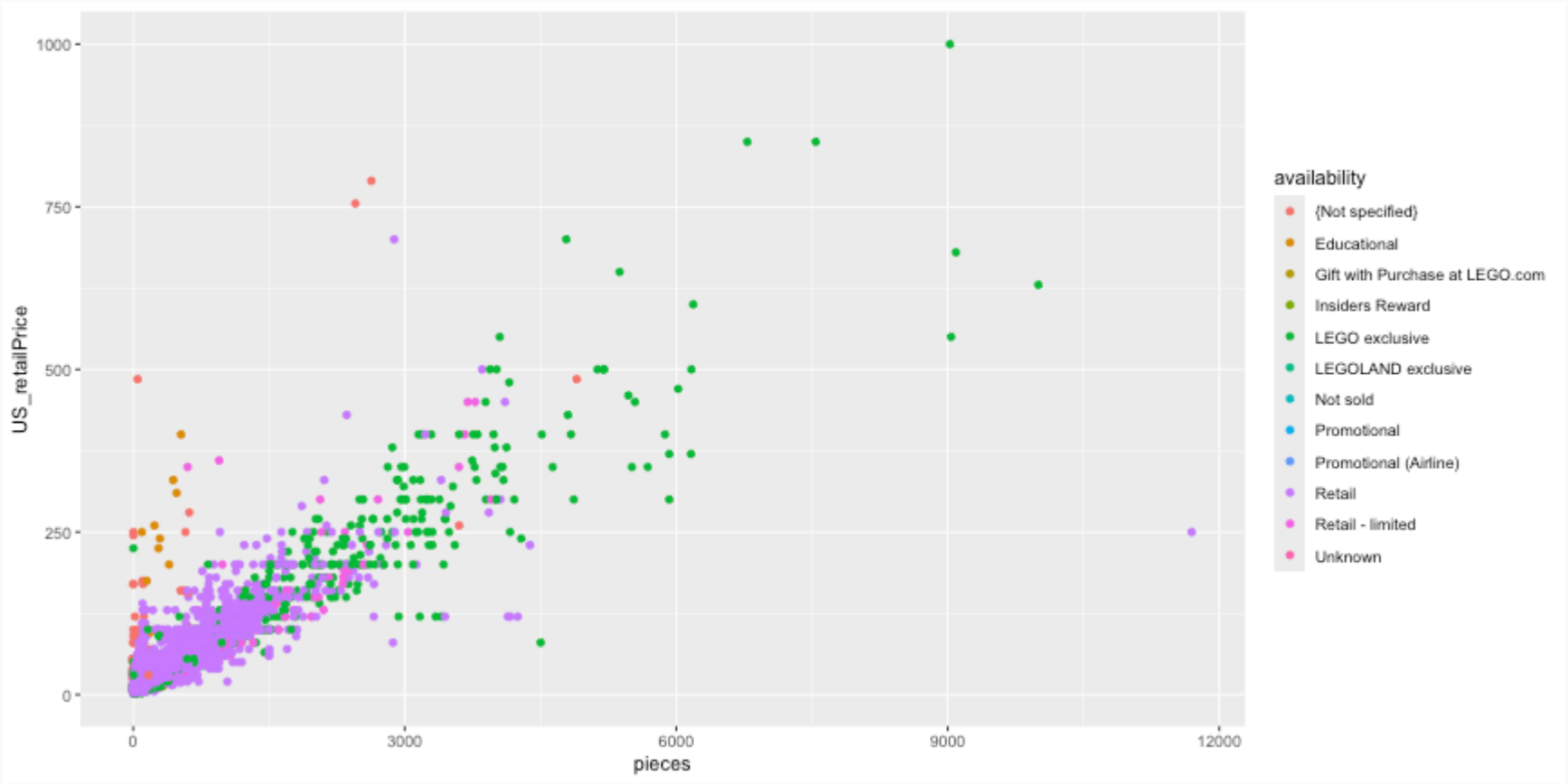
Scatterplot

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



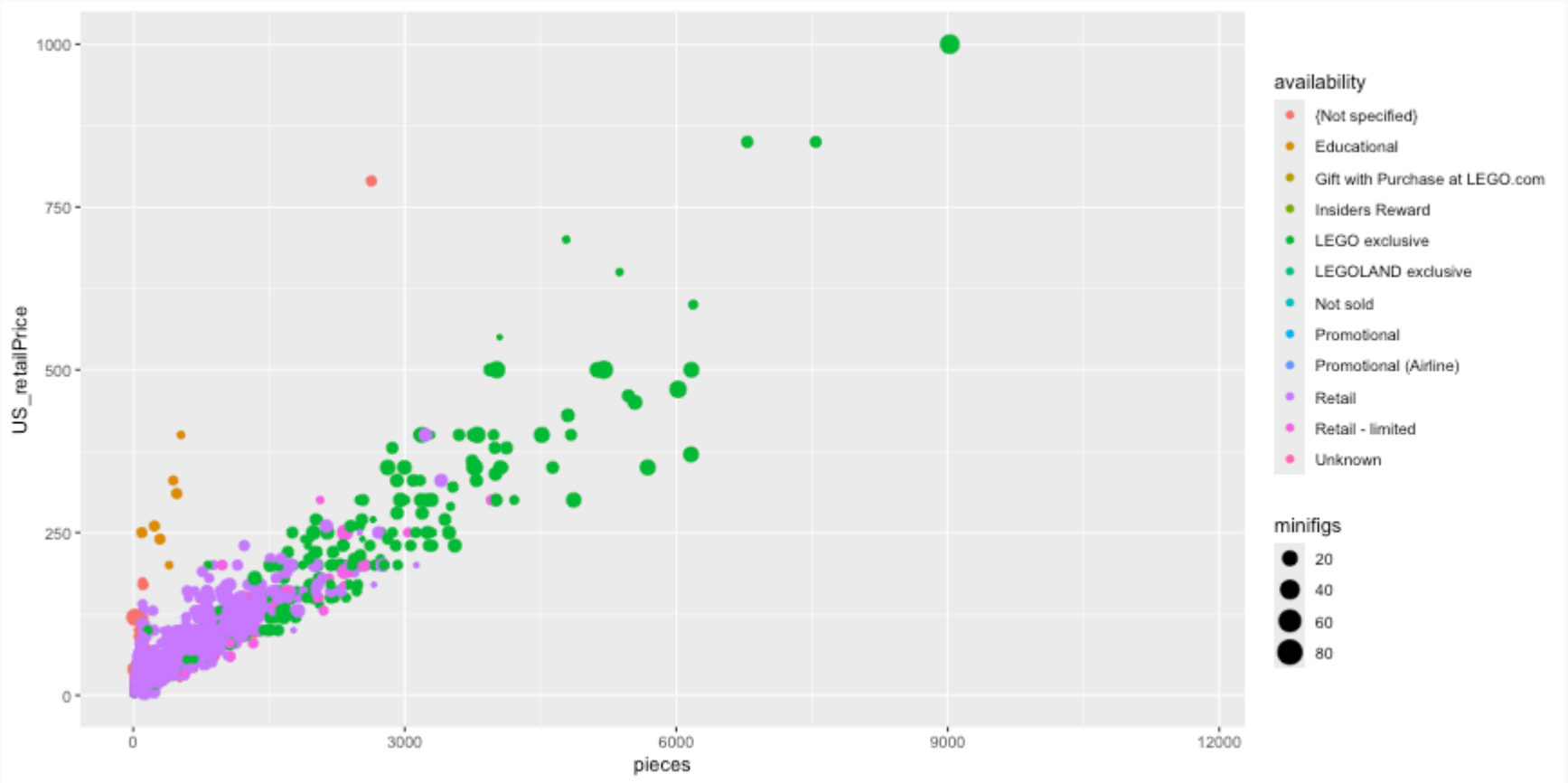
Scatterplot (cont.)

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



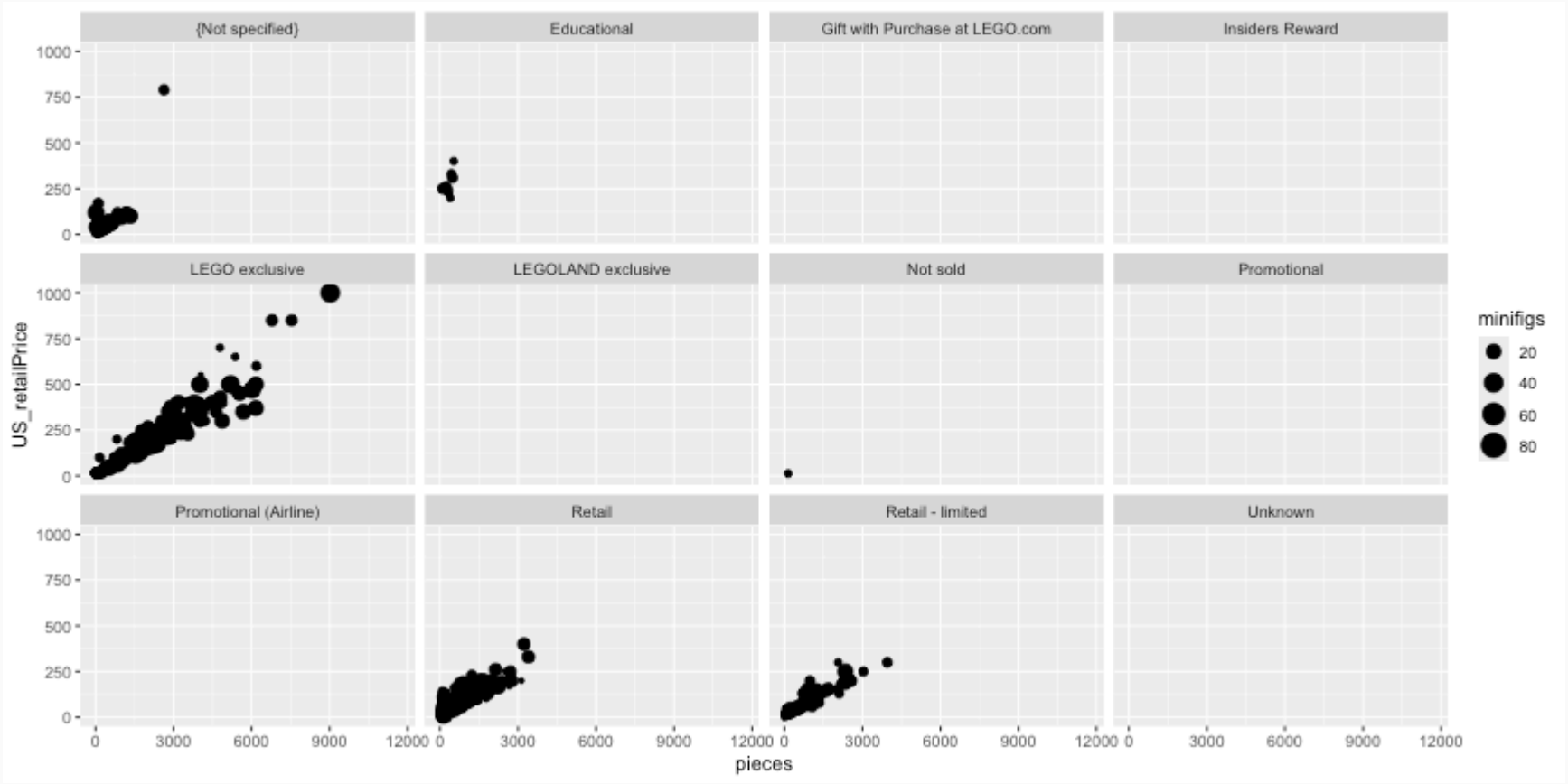
Scatterplot (cont.)

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



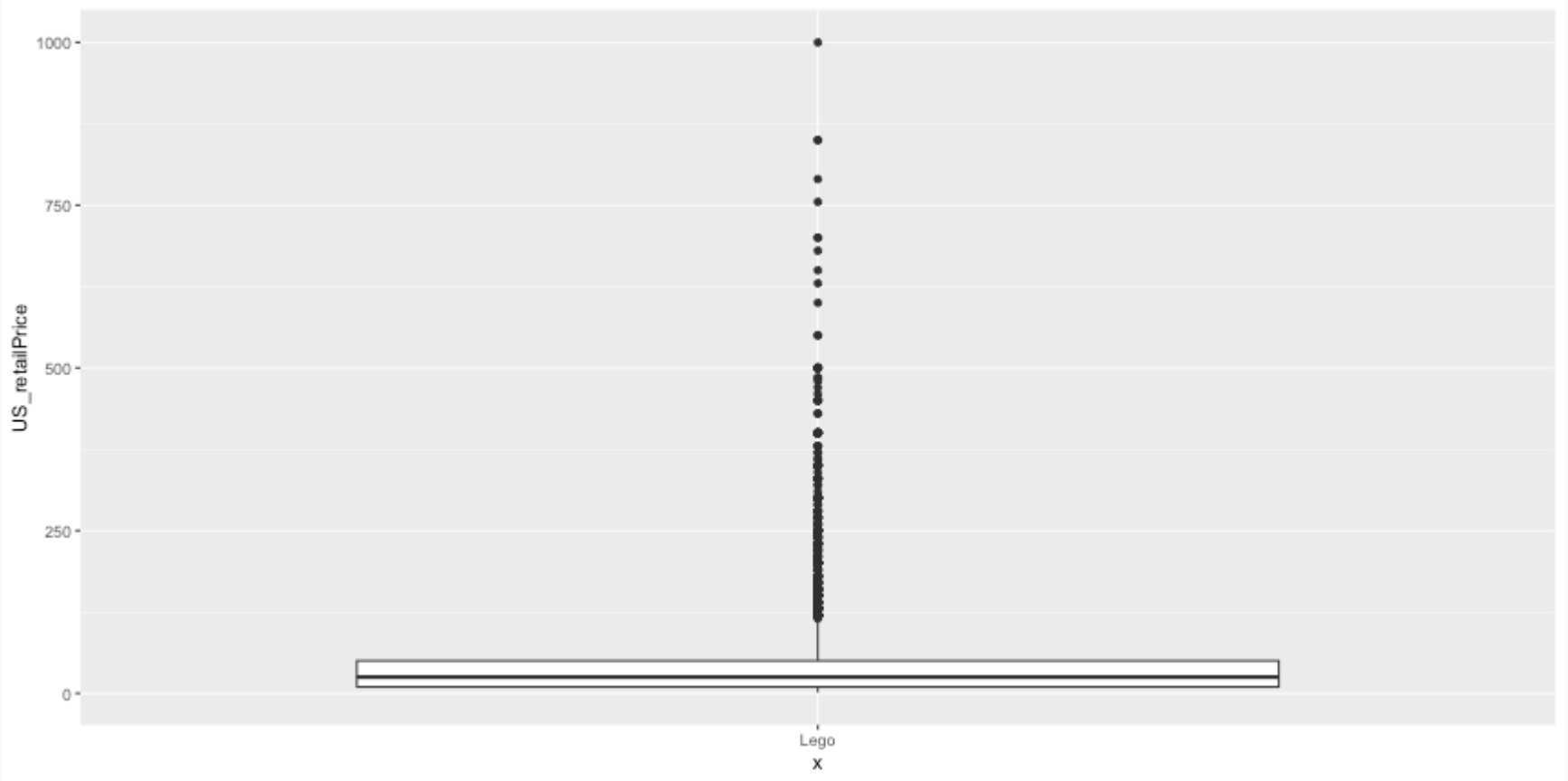
Scatterplot (cont.)

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



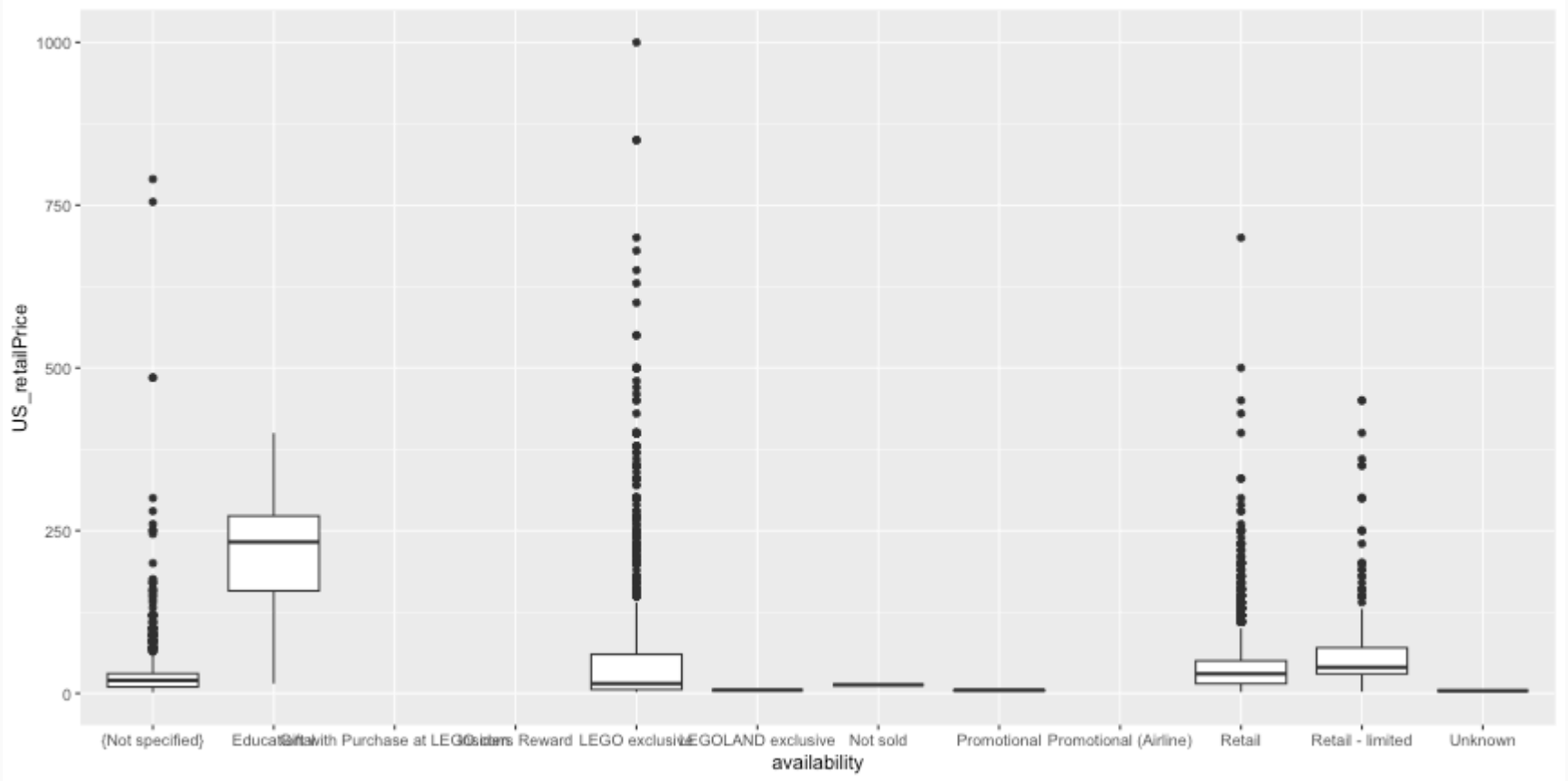
Boxplots

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



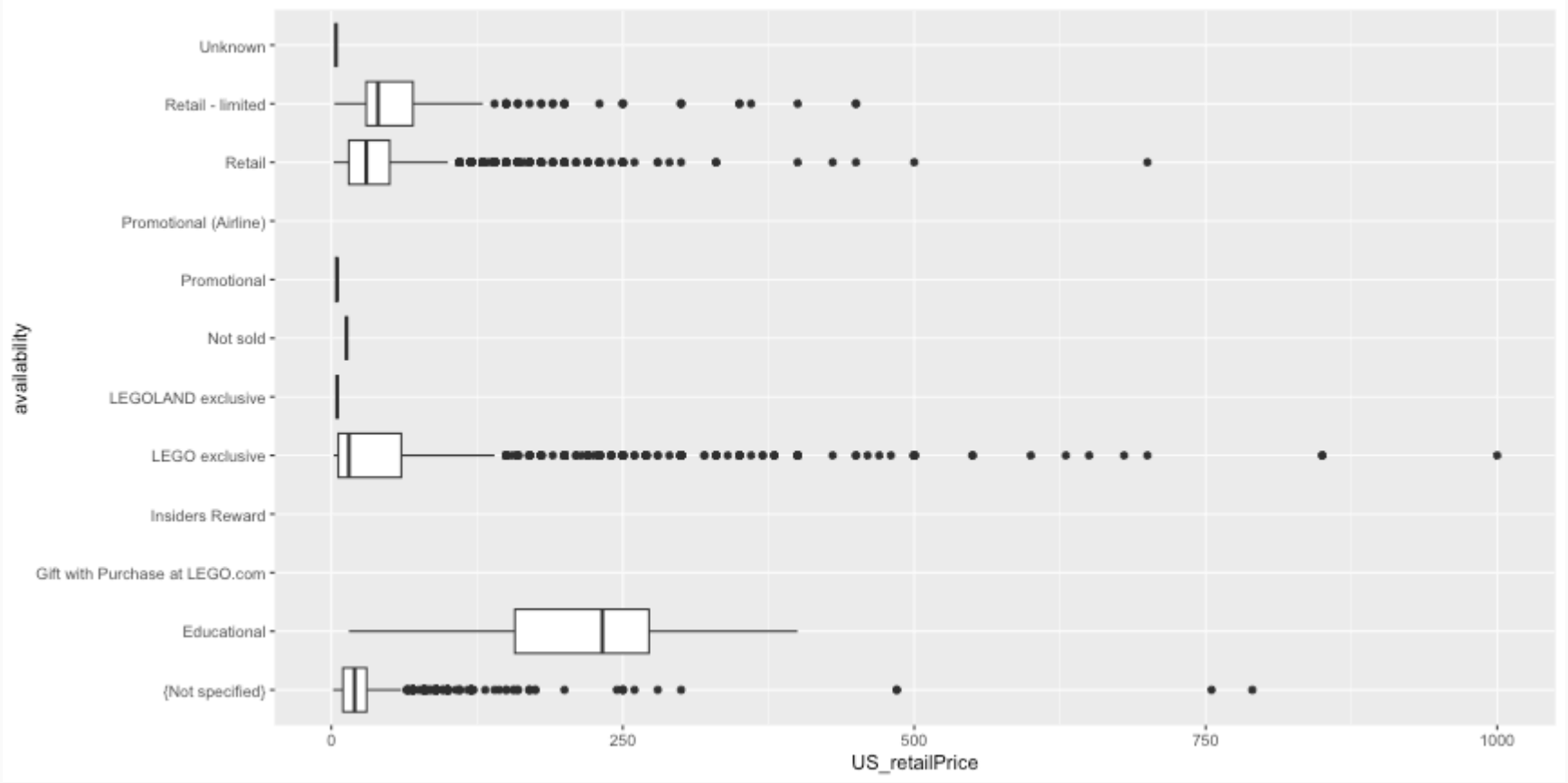
Boxplots (cont.)

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



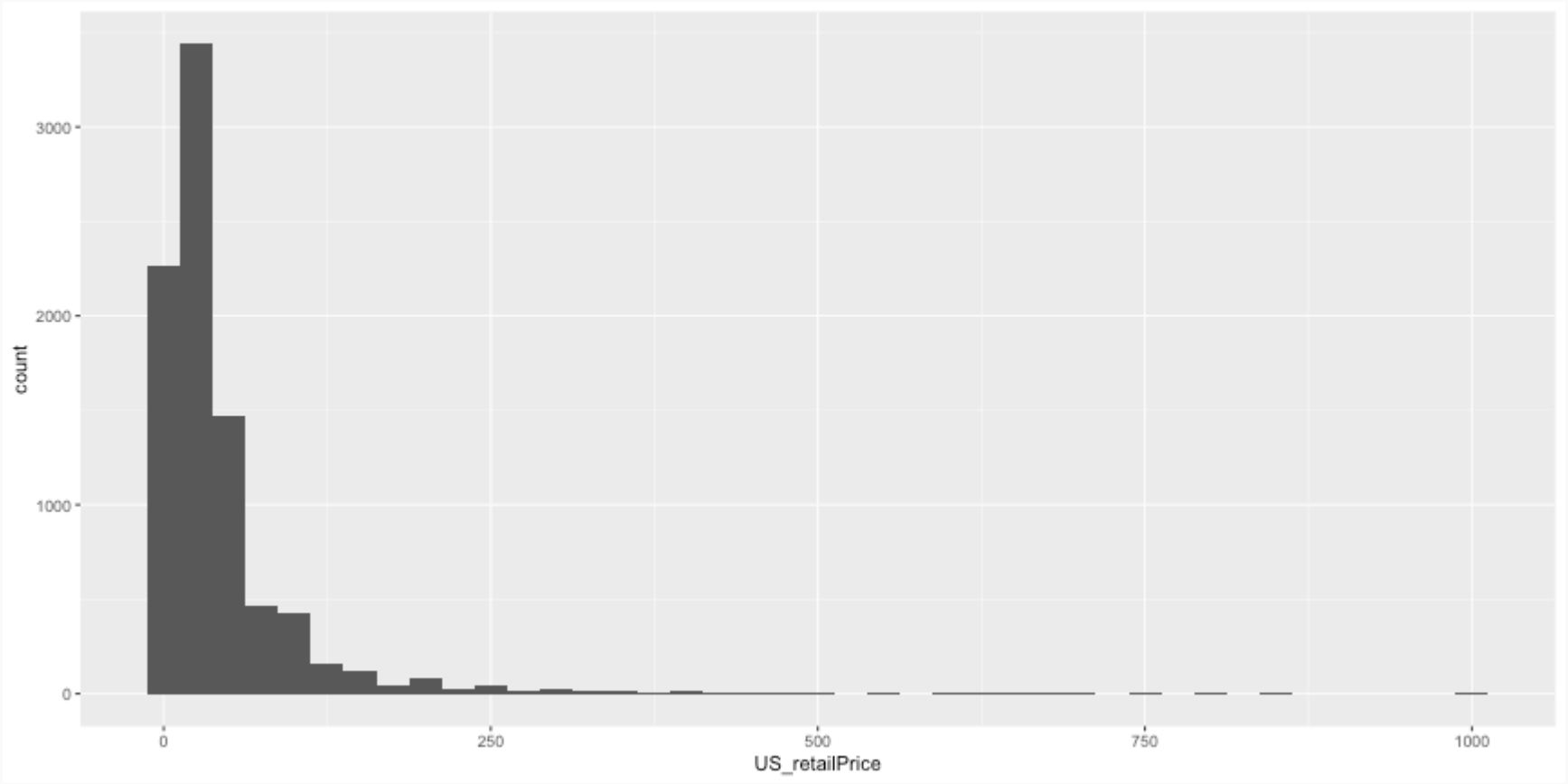
Boxplot (cont.)

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



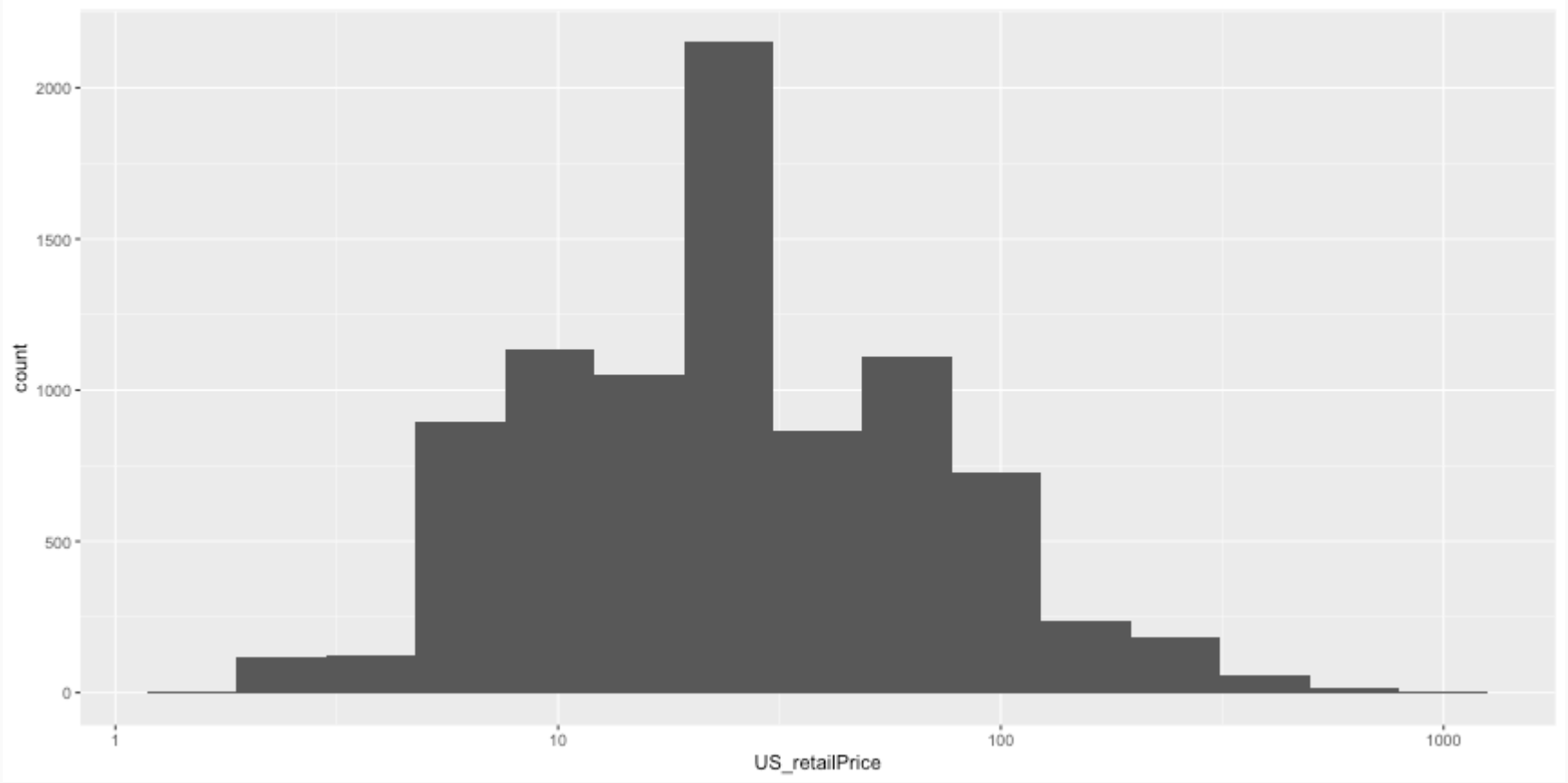
Histograms

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



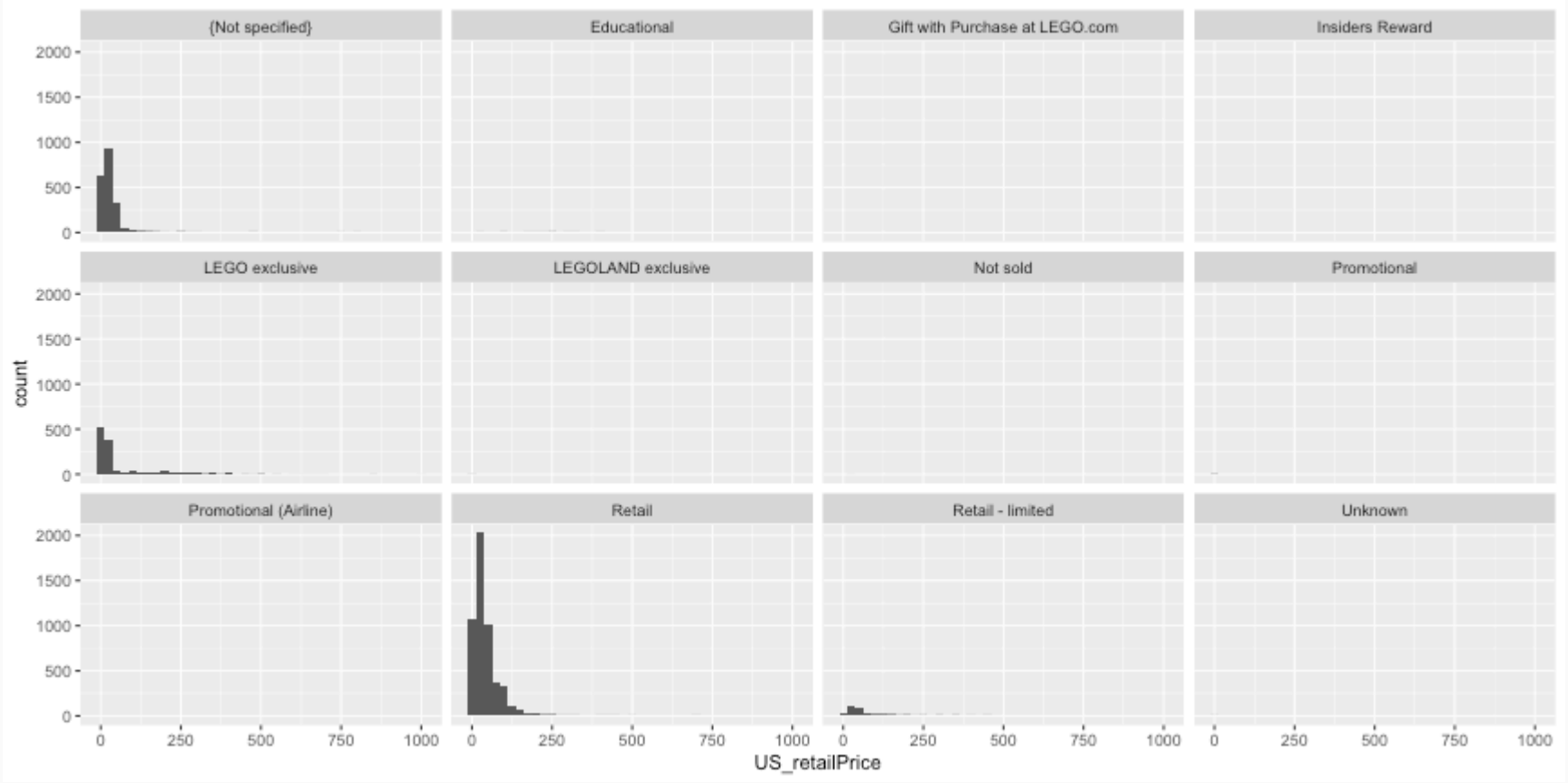
Histograms (cont.)

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



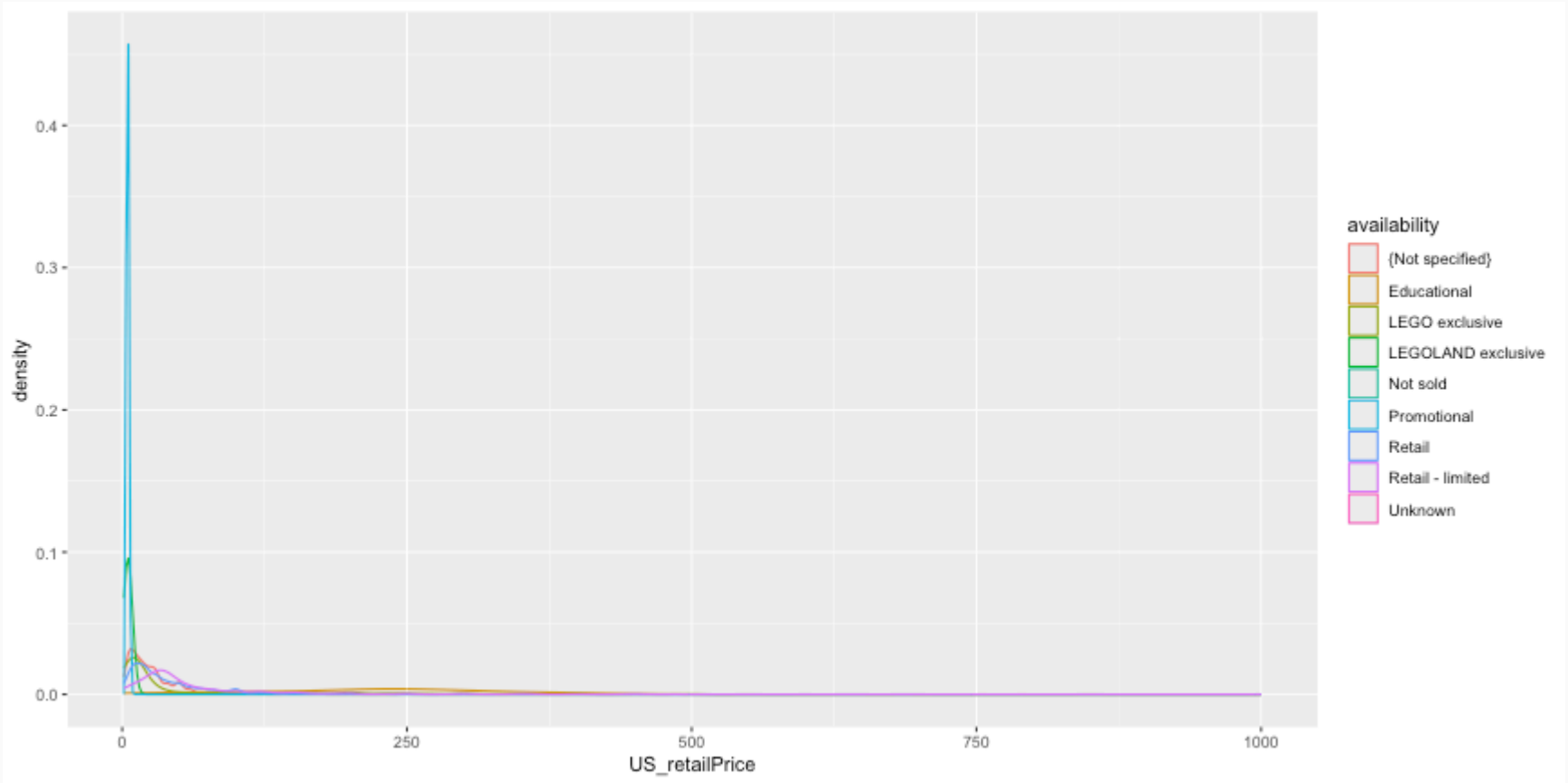
Histograms (cont.)

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



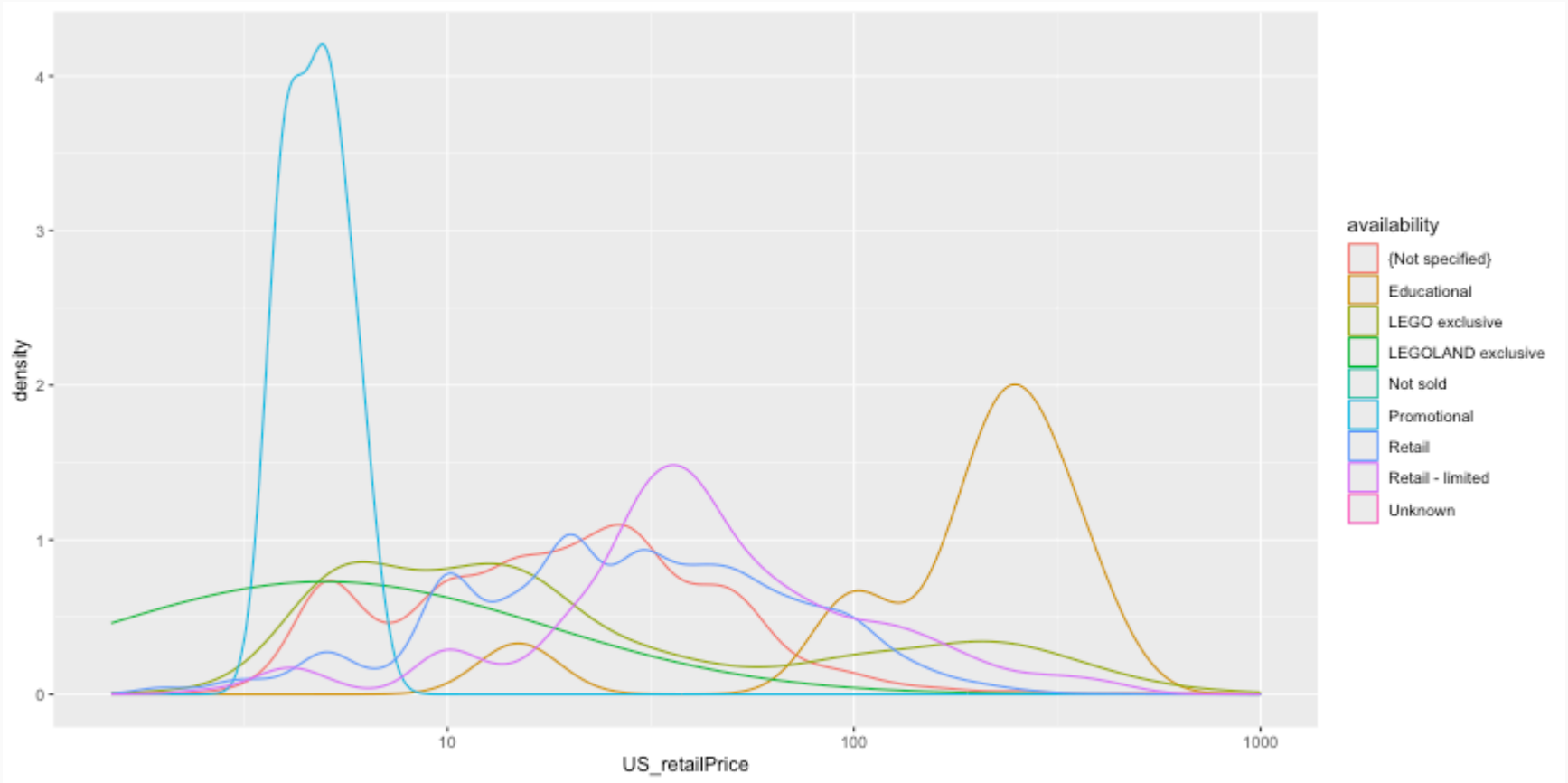
Density Plots

```
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()
```



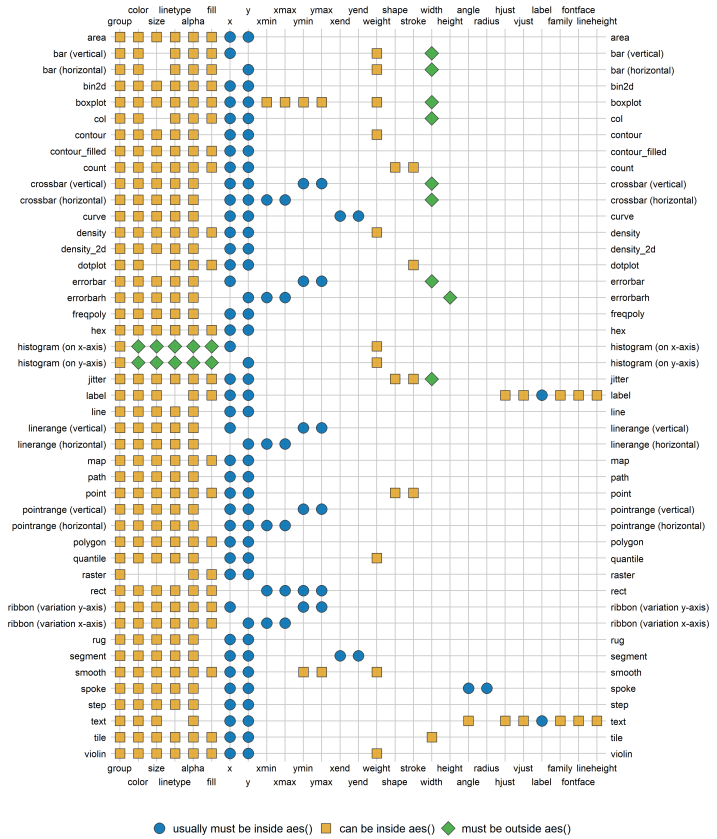
ggplot2 aesthetics

ggplot2 aesthetics cheat sheet

Use this table to find the right aesthetics for your geoms:

Aesthetics that usually must be mapped to the data: use inside aes()
Aesthetics that can be mapped to the data: use in or outside aes()
Aesthetics that cannot be mapped to the data: use outside aes()

e.g., ggplot(mpg, aes(x = class, y = displ)) + geom_col(aes(fill = class), width = .9)

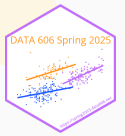


idea and design: Christian Burkhart
design advice: Ida Aarnio

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."))
```



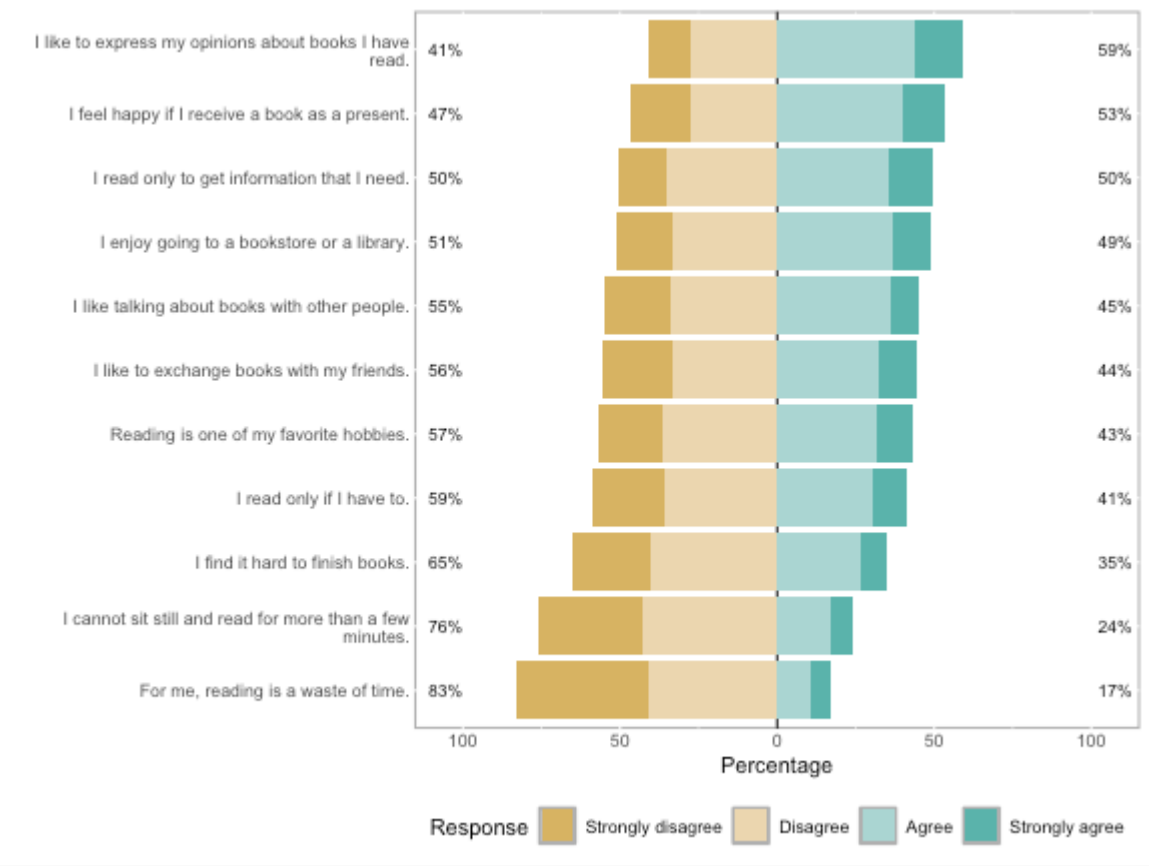
likert R Package

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

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

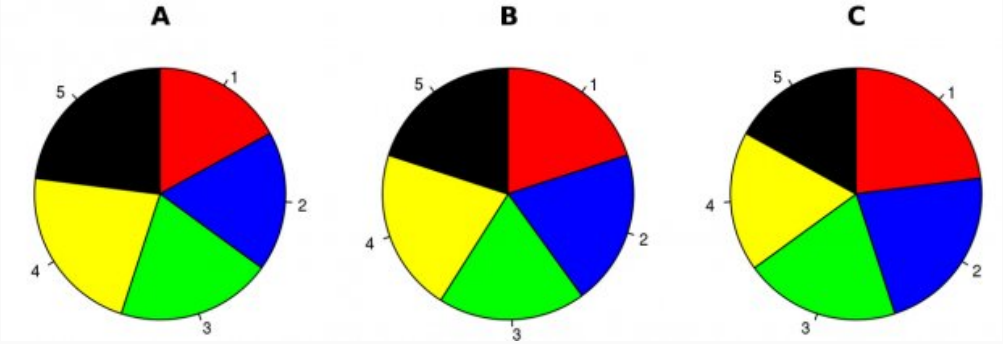
likert Plots

```
plot(l24)
```



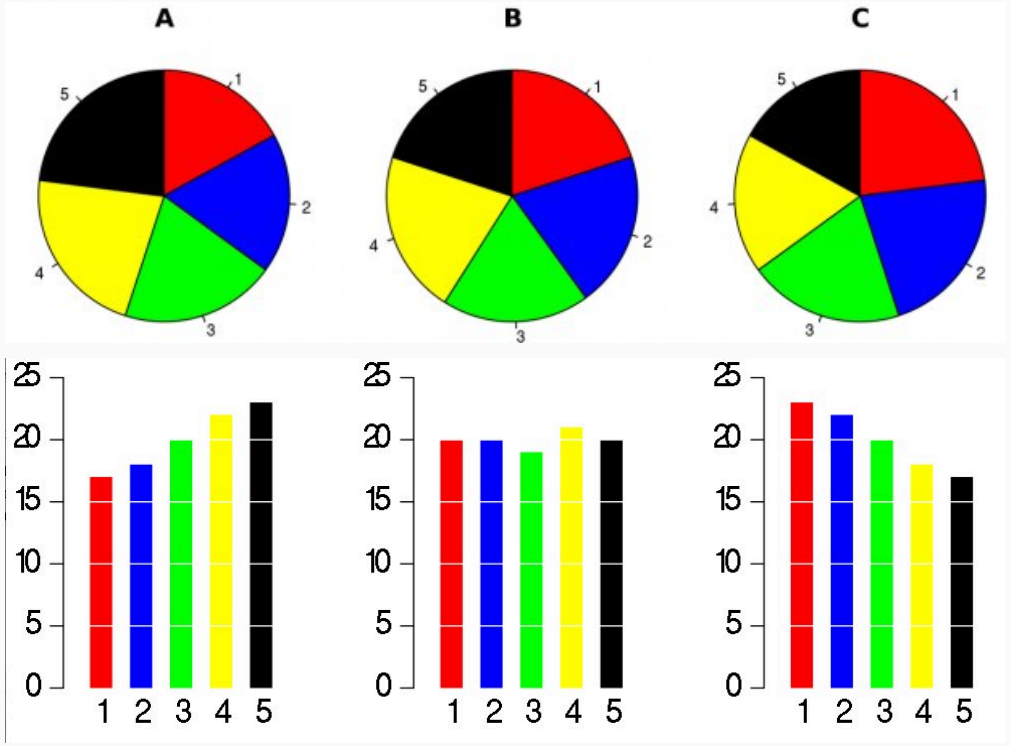
Pie Charts

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.



Pie Charts

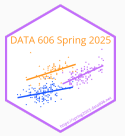
There is only one pie chart in *OpenIntro Statistics* (Diez, Barr, & Çetinkaya-Rundel, 2015, p. 48). Consider the following three pie charts that represent the preference of five different colors. Is there a difference between the three pie charts? This is probably a difficult to answer.



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



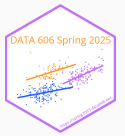
Additional Resources

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/bz8GvYWfKdMggRv38