Summarizing Data Part 2

DATA 606 - Statistics & Probability for Data Analytics

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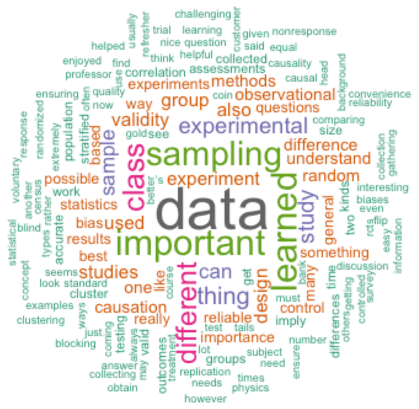
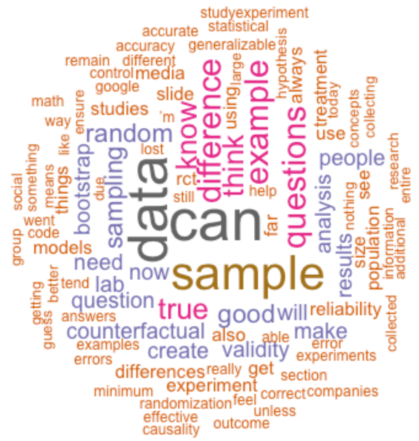
September 18, 2024

One Minute Paper Results

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



What important question remains unanswered for you?



DATA 606 Fall 2024

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

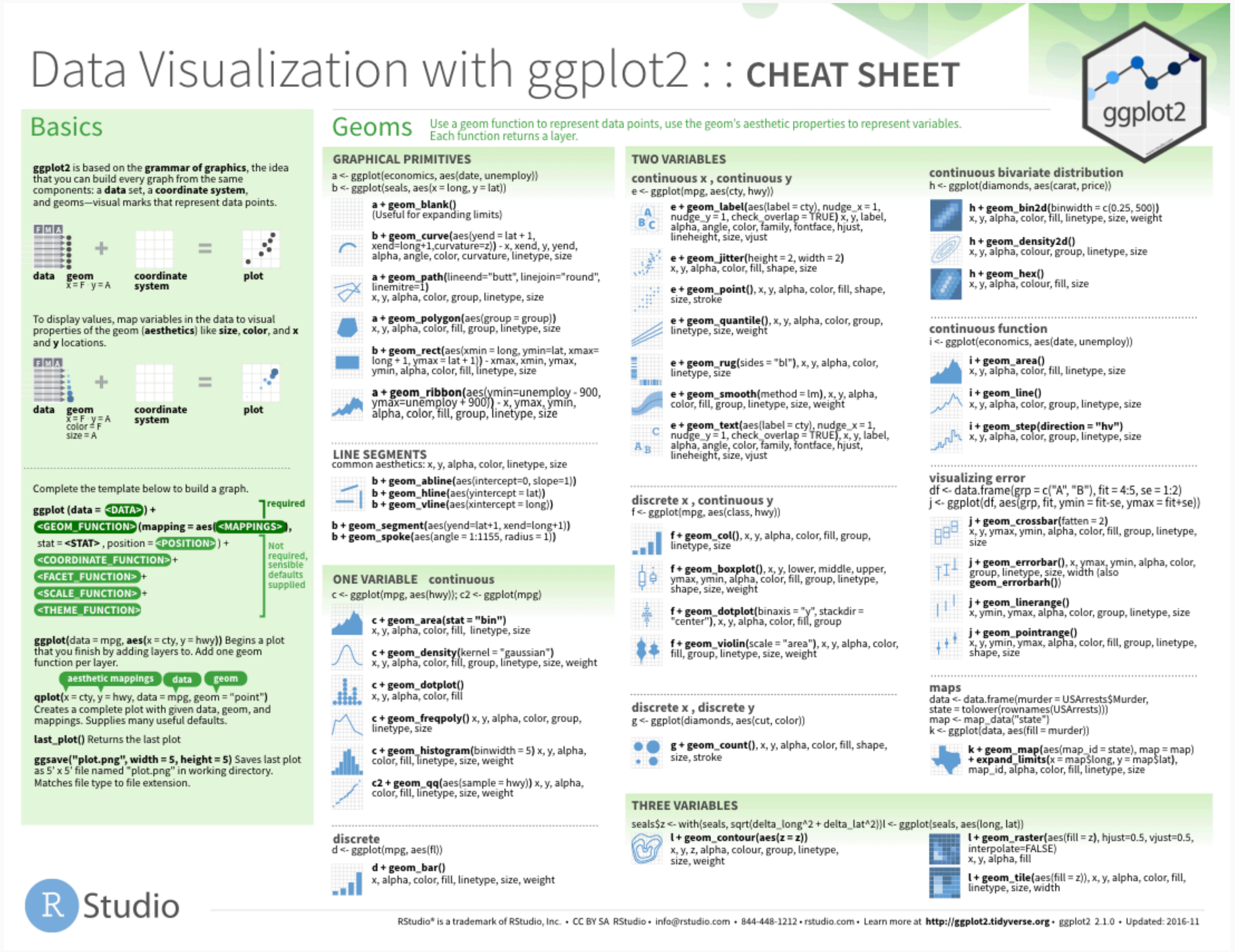
  `ggtitle('my title')`, `ylim(c(0, 10000))`, `xlab('x-axis label')`

Lots of geoms

```r
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.

F M A
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.

Complete the template below to build a graph.

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

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

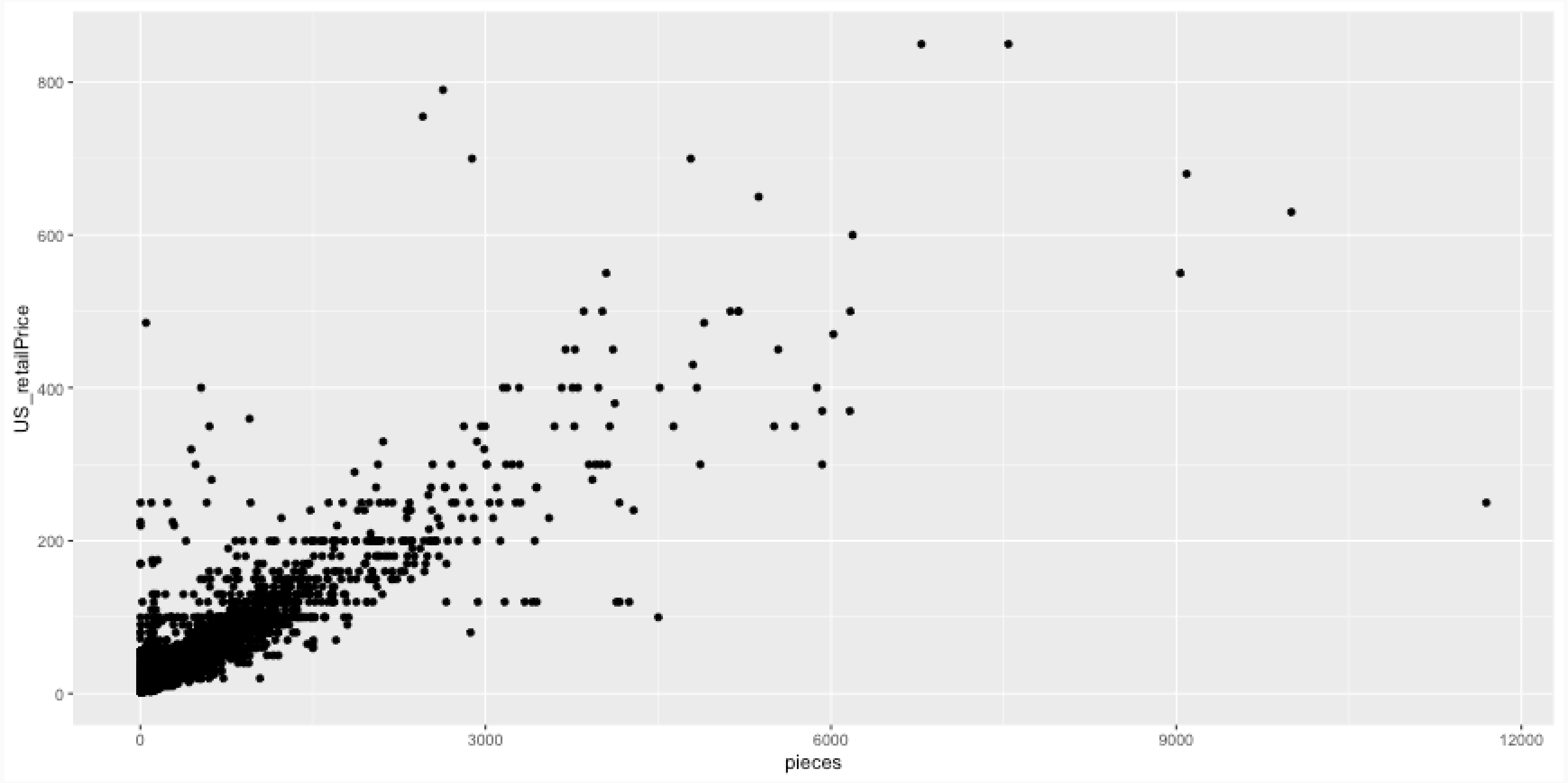
l + geom_raster(aes(fill = z)**)**, hjust=0.5, vjust=0.5, interpolate=FALSE)
x, y, alpha, fill

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

RStudio

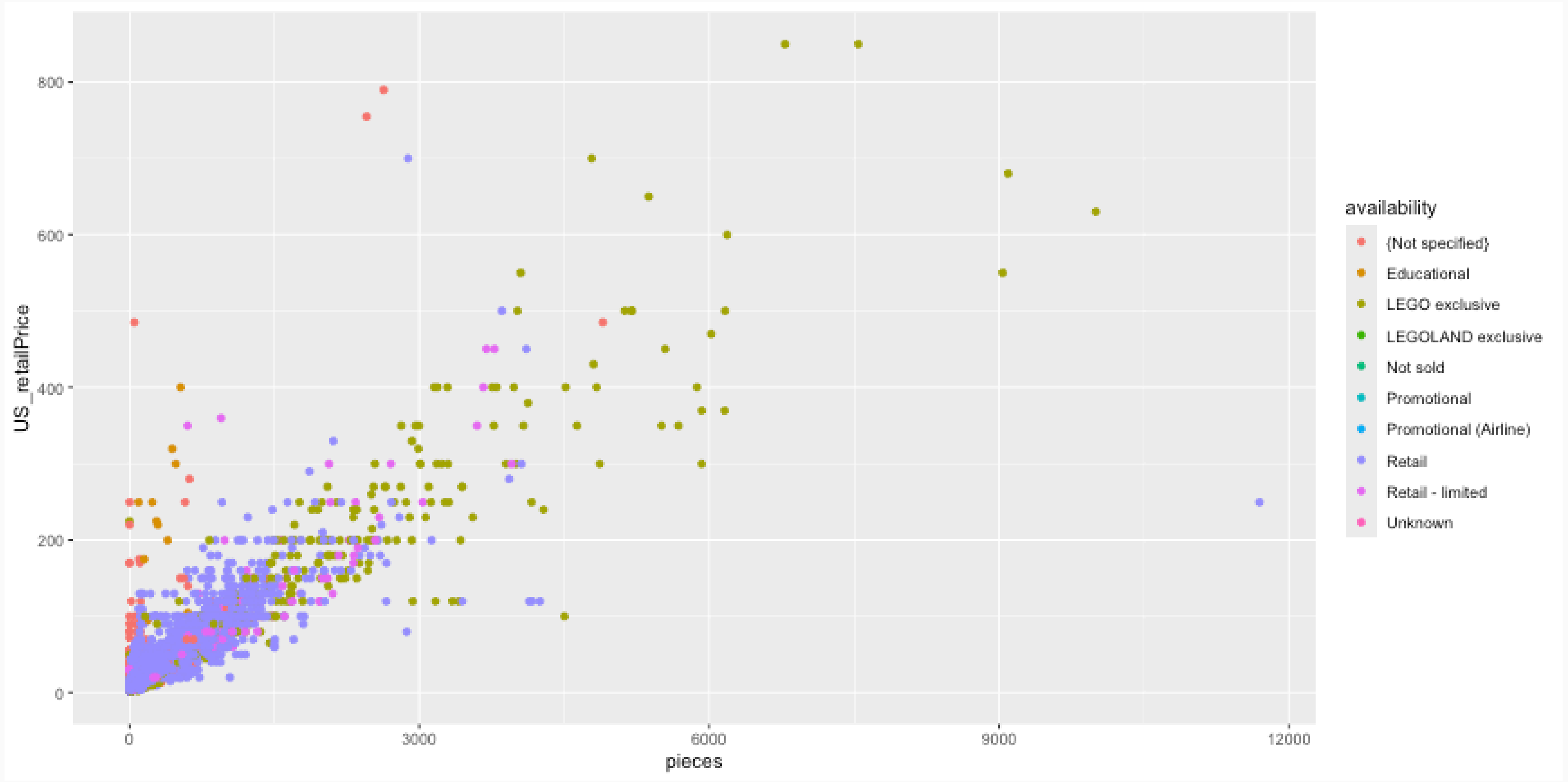
Scatterplot

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



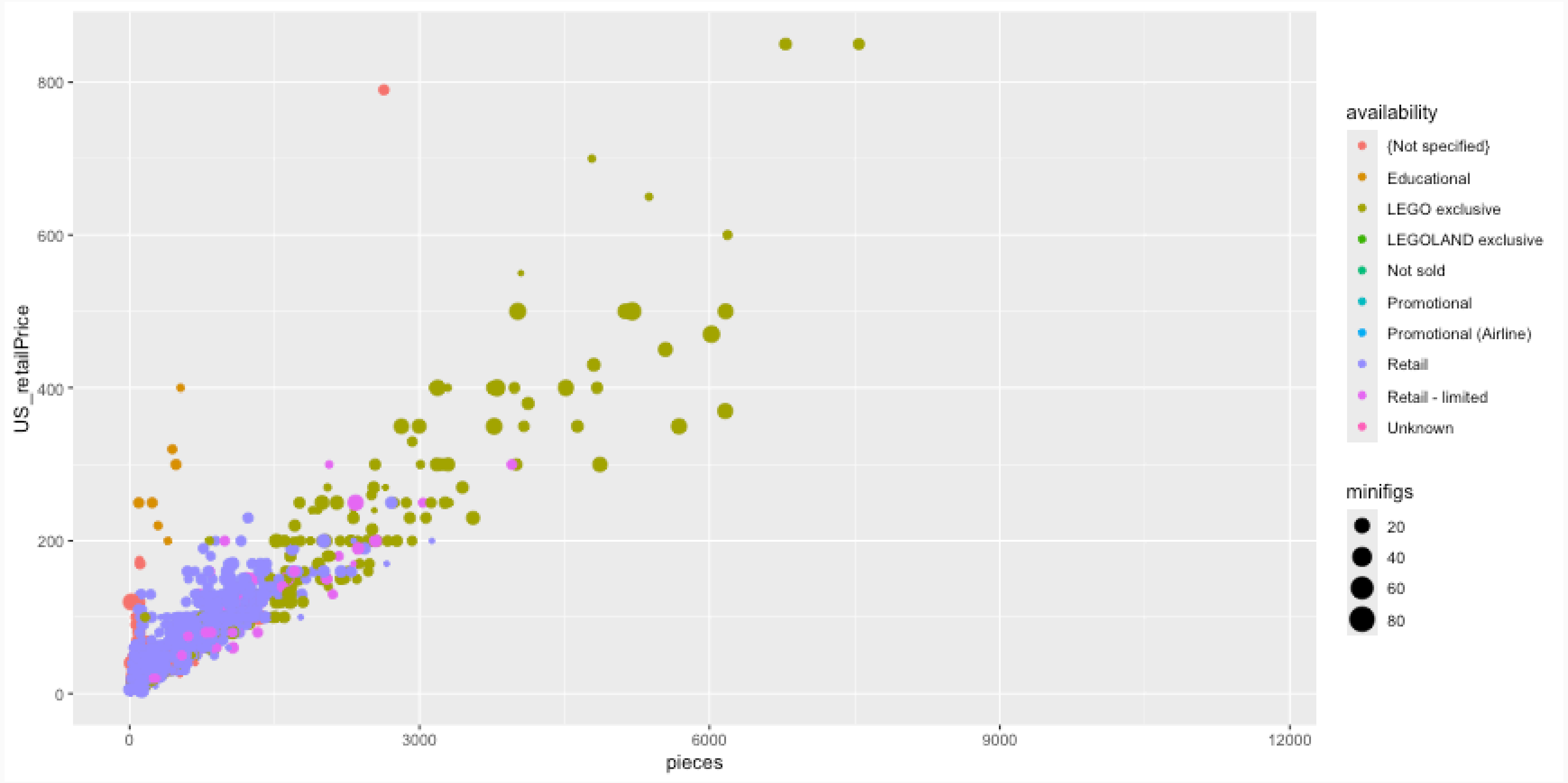
Scatterplot (cont.)

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



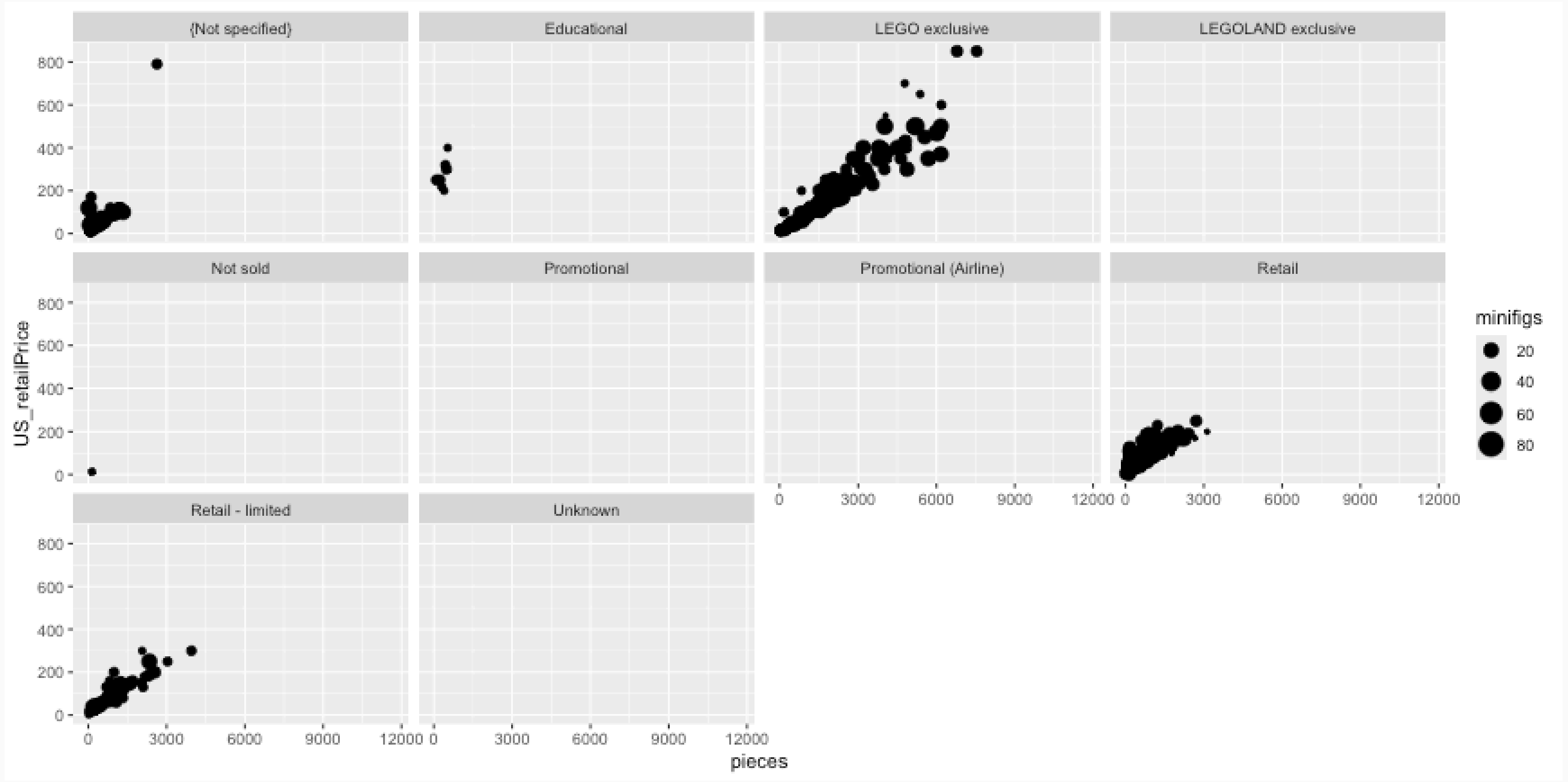
Scatterplot (cont.)

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



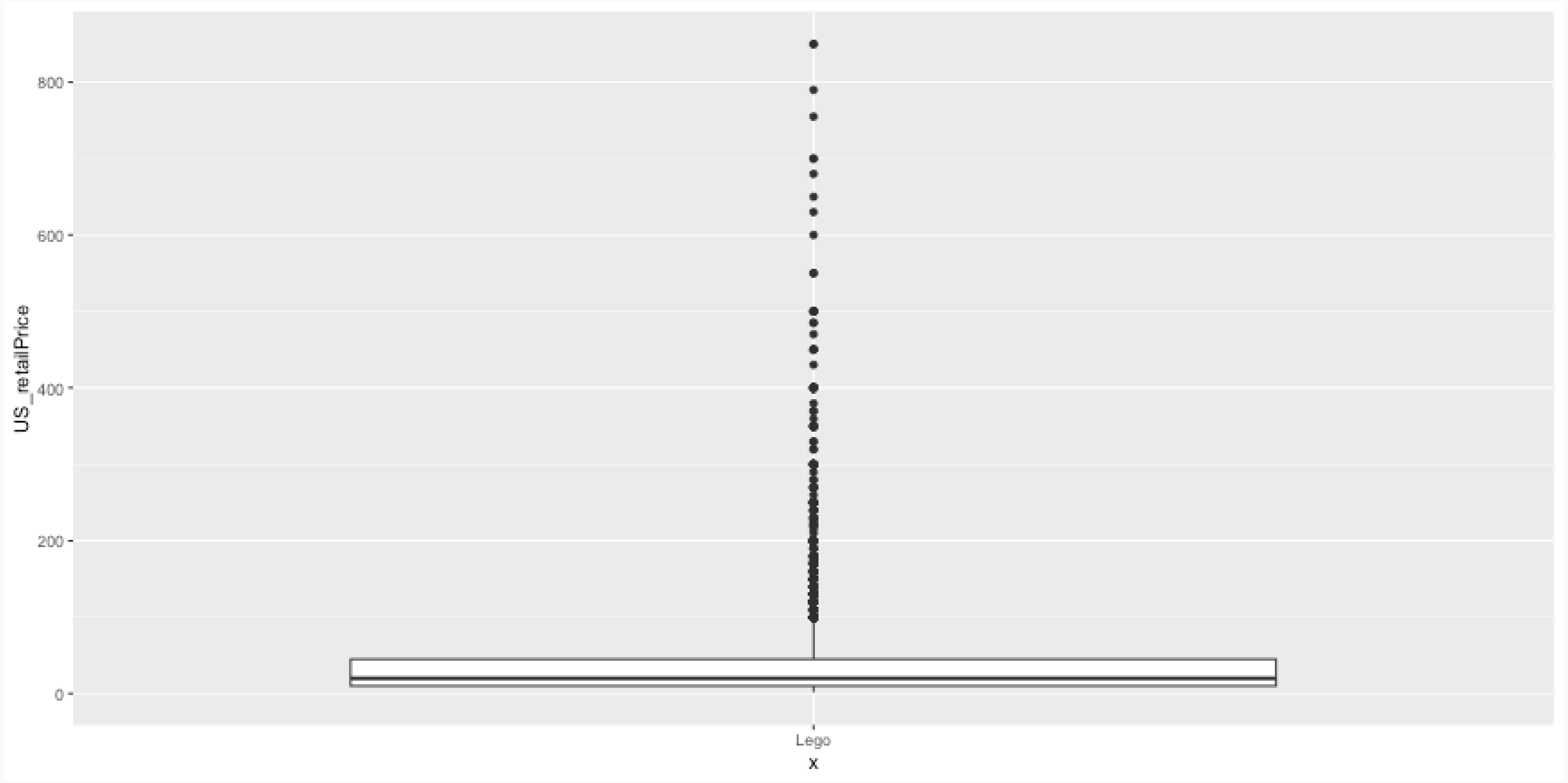
Scatterplot (cont.)

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



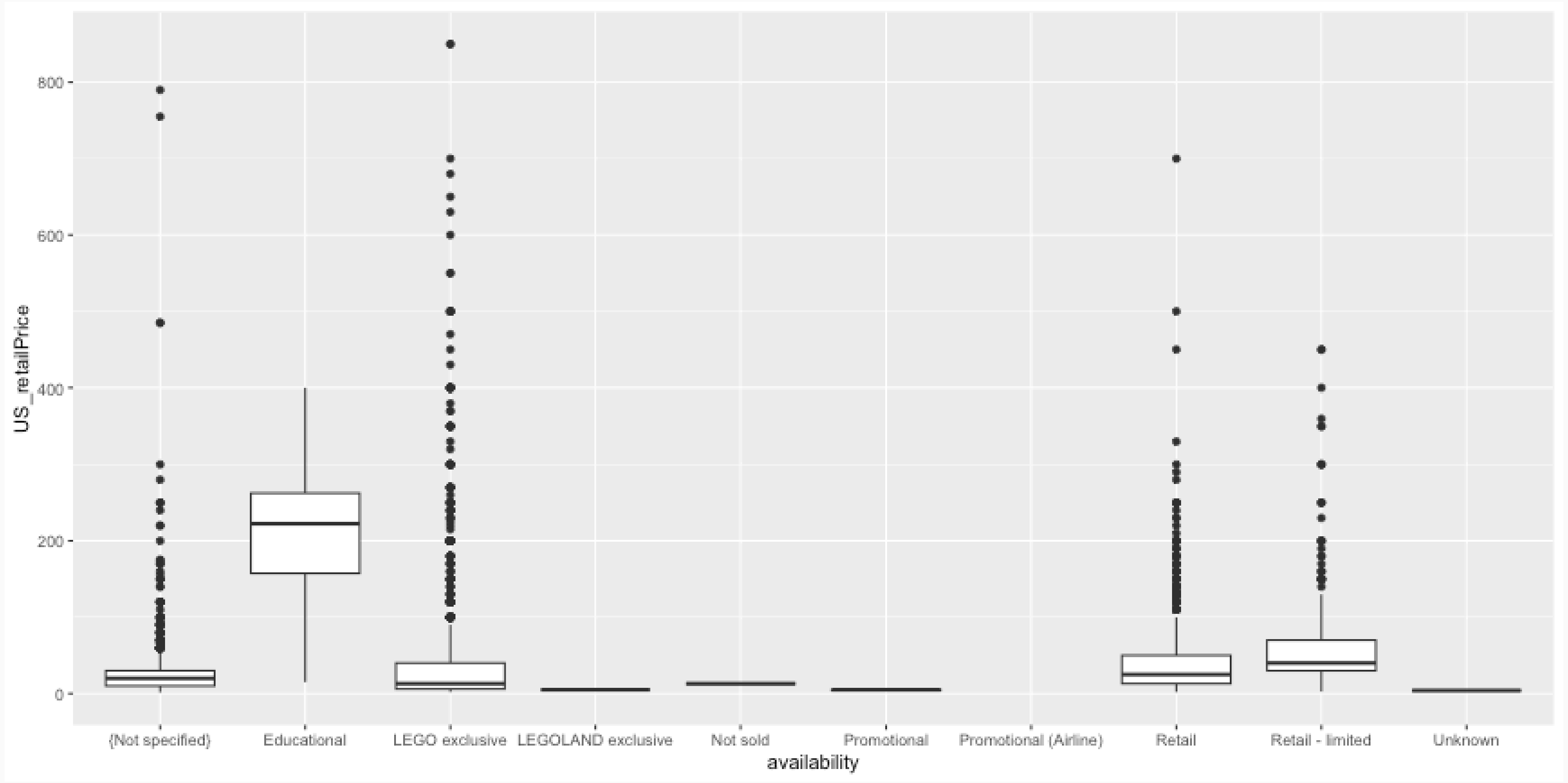
Boxplots

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



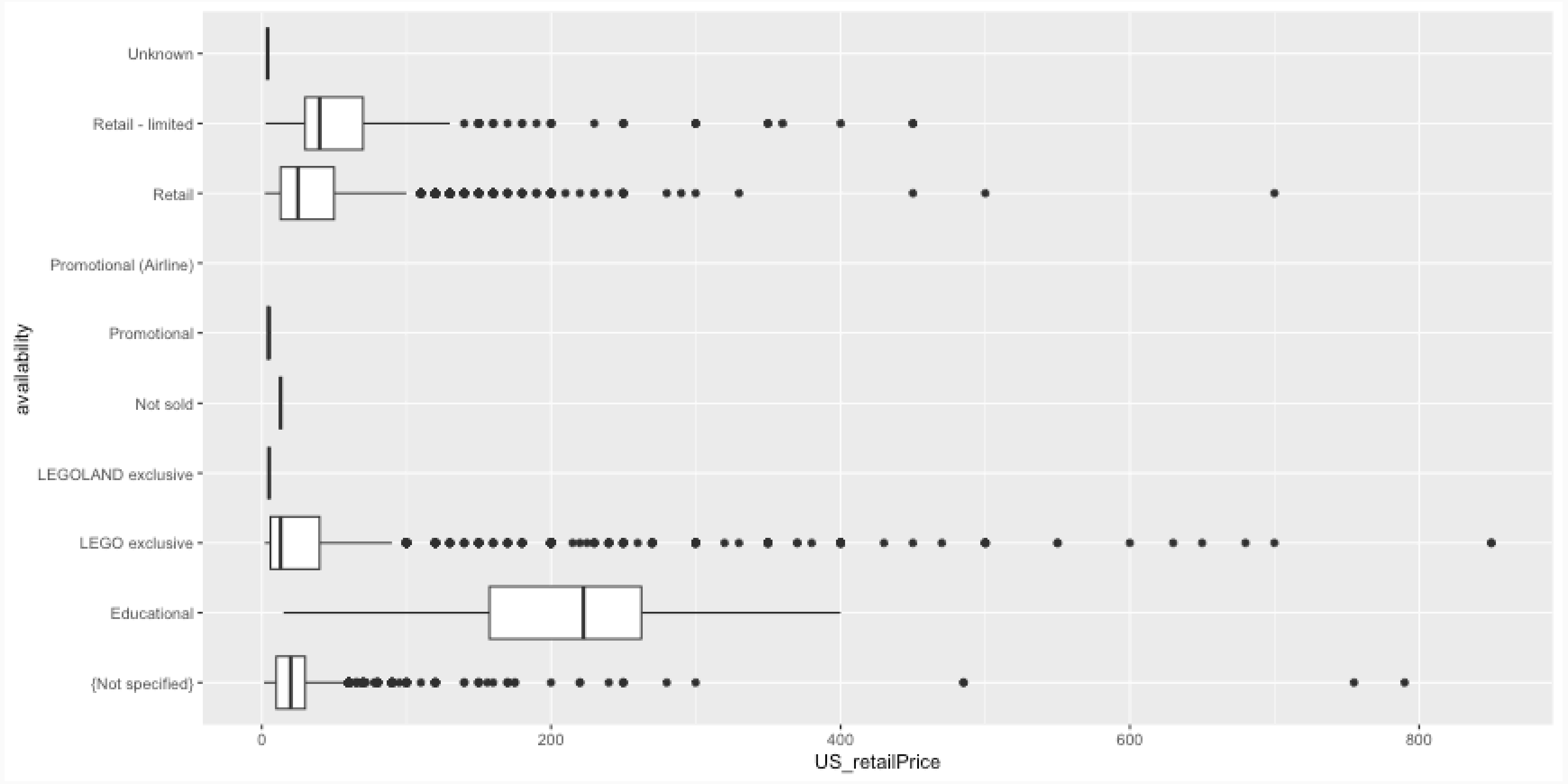
Boxplots (cont.)

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



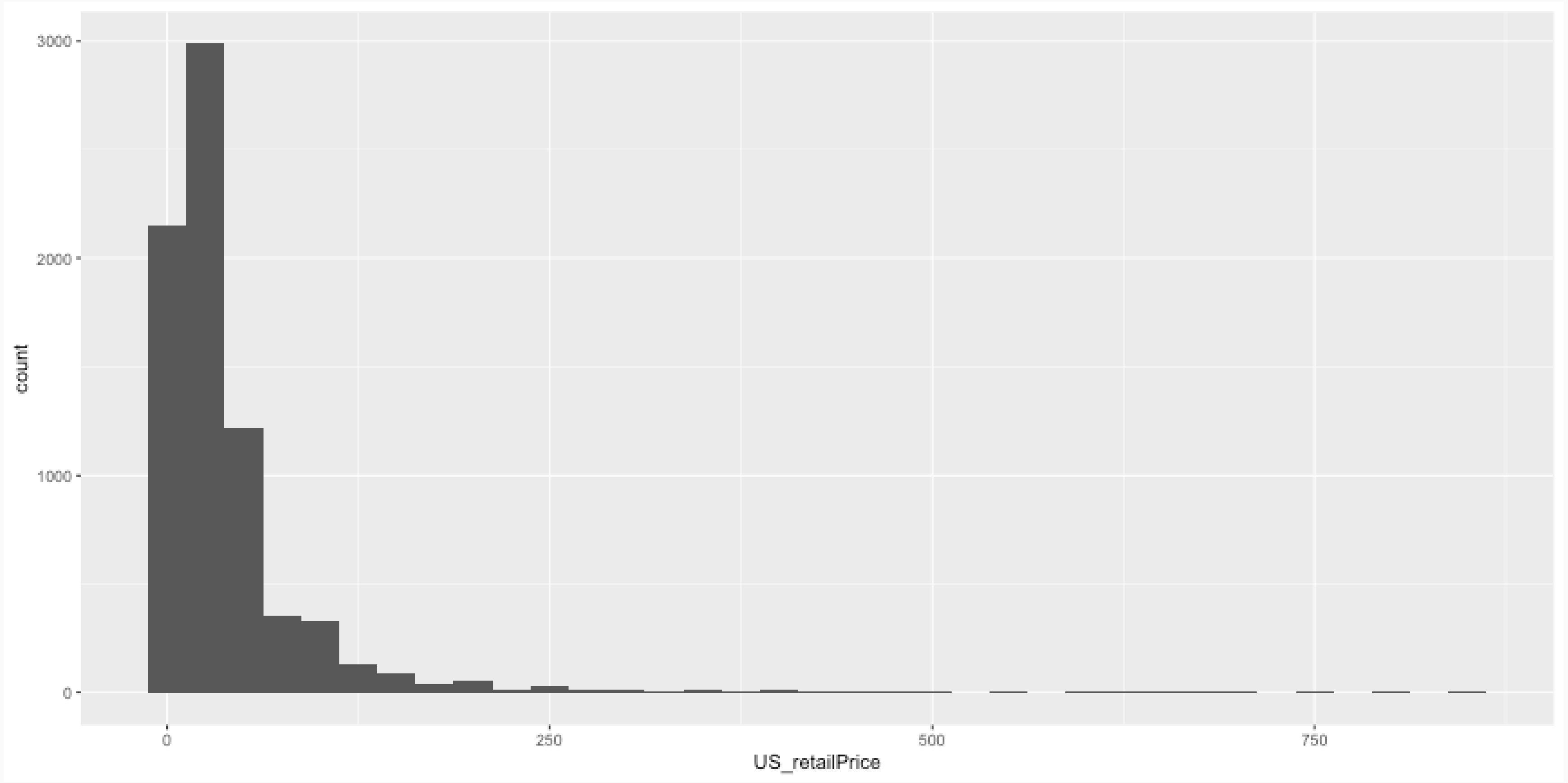
Boxplot (cont.)

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



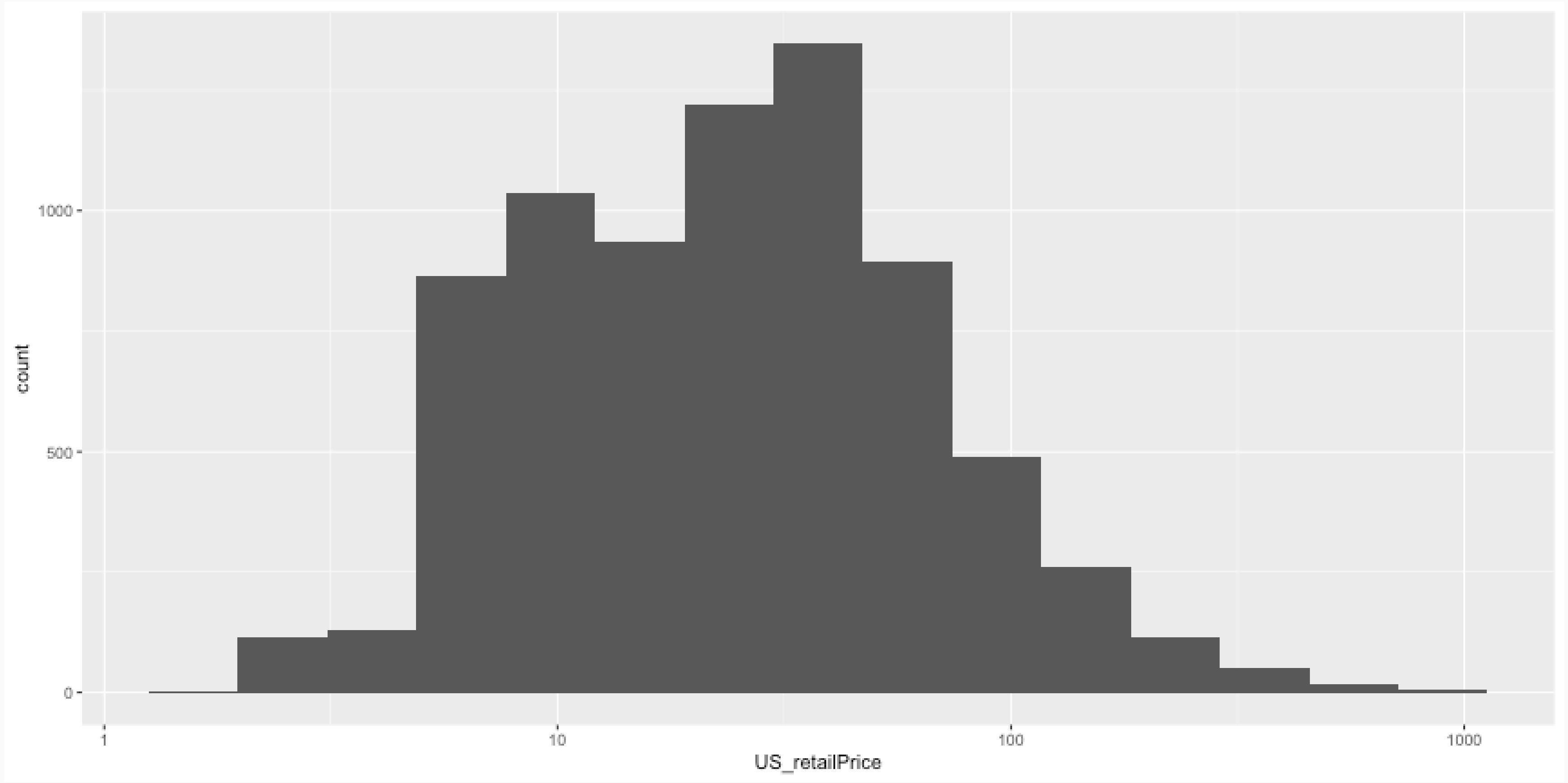
Histograms

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



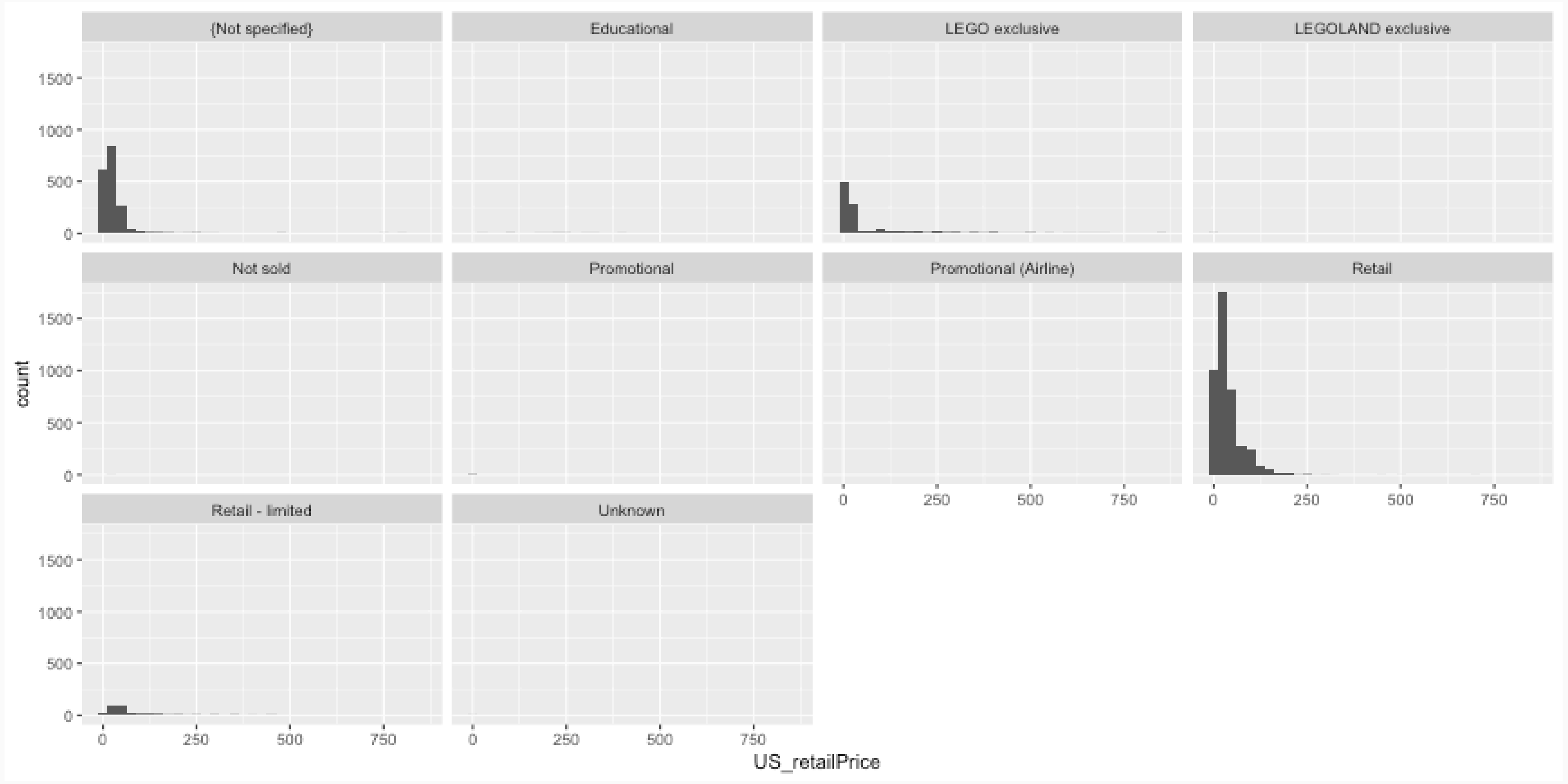
Histograms (cont.)

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



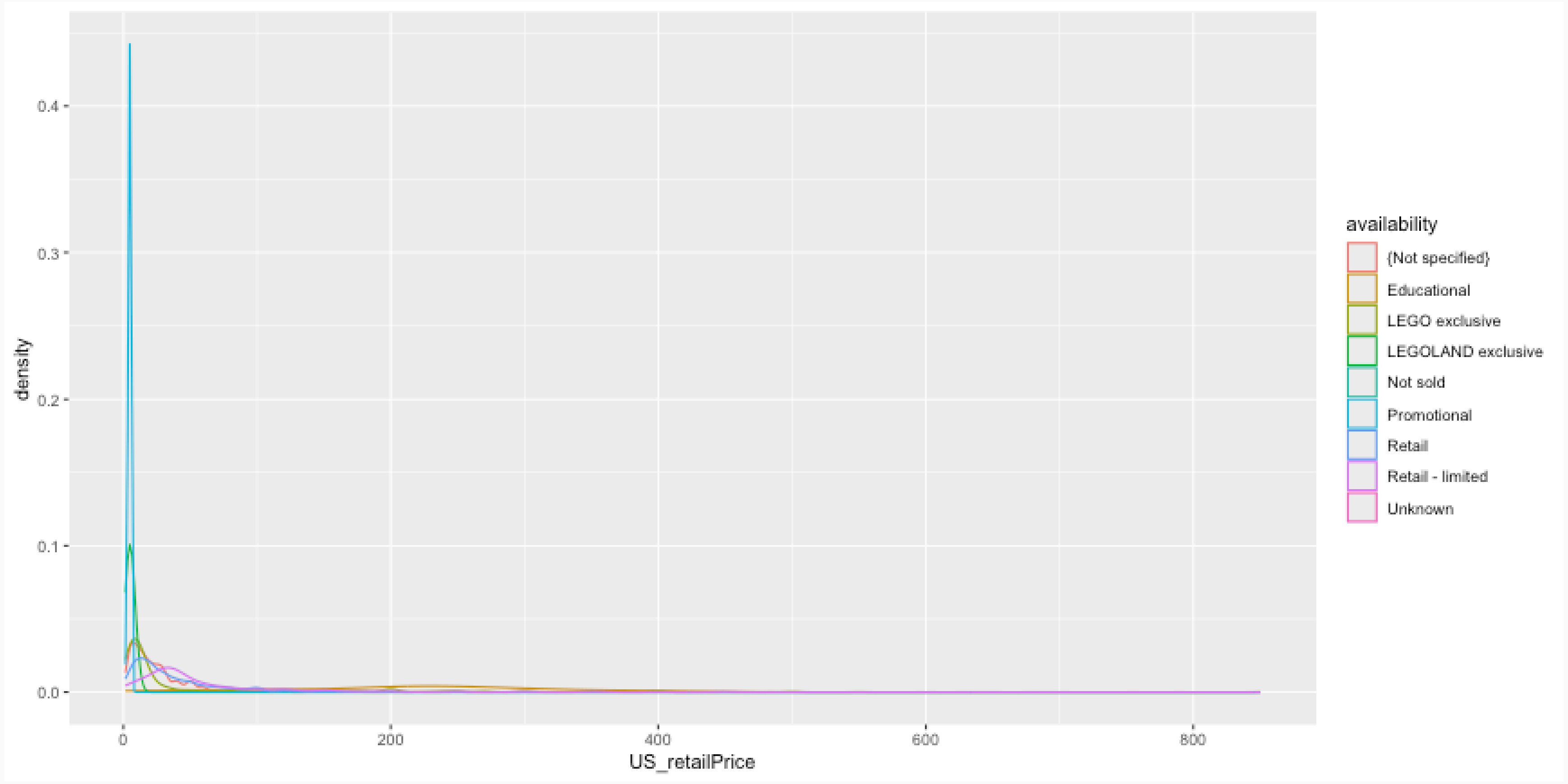
Histograms (cont.)

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



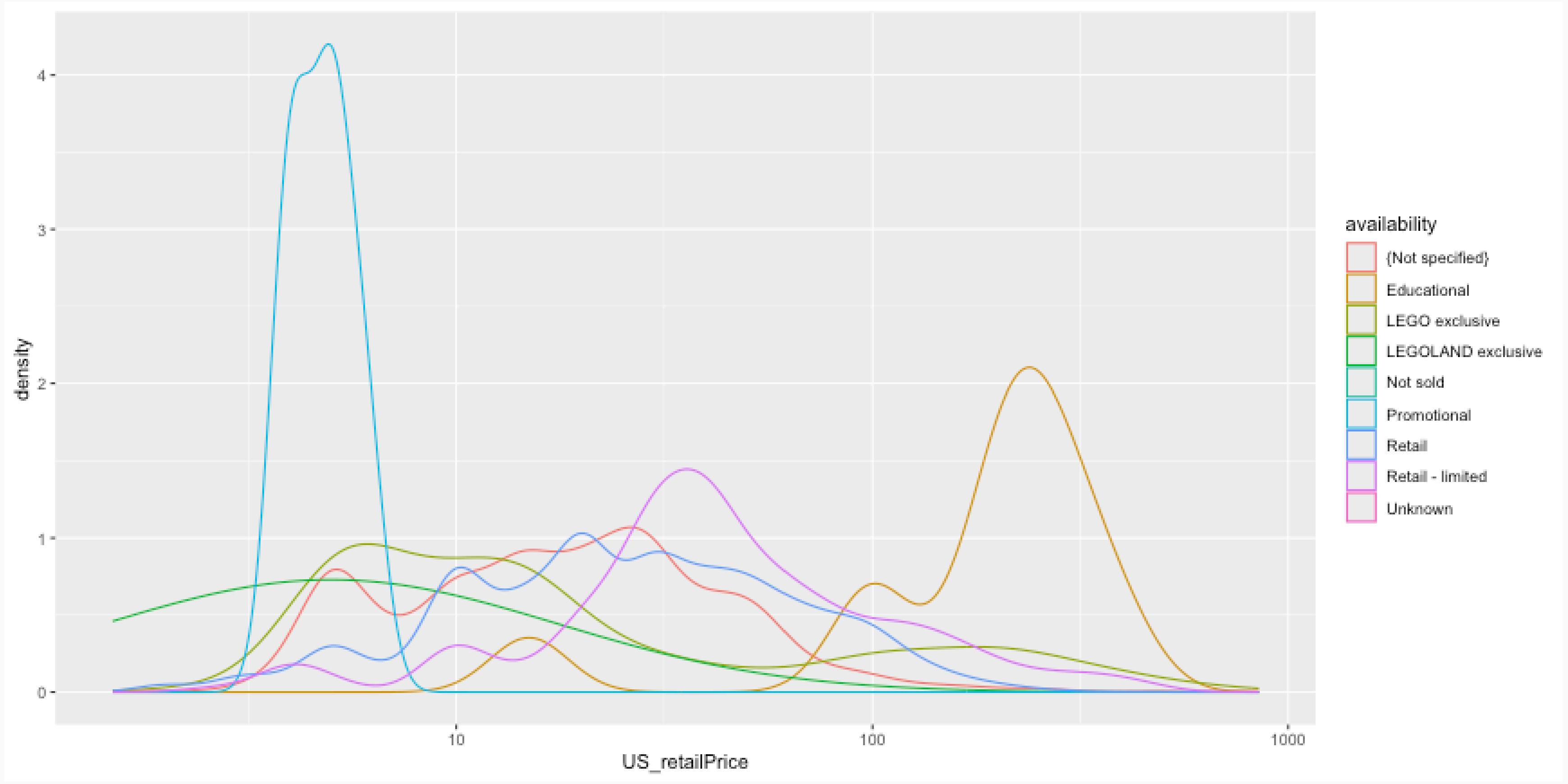
Density Plots

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

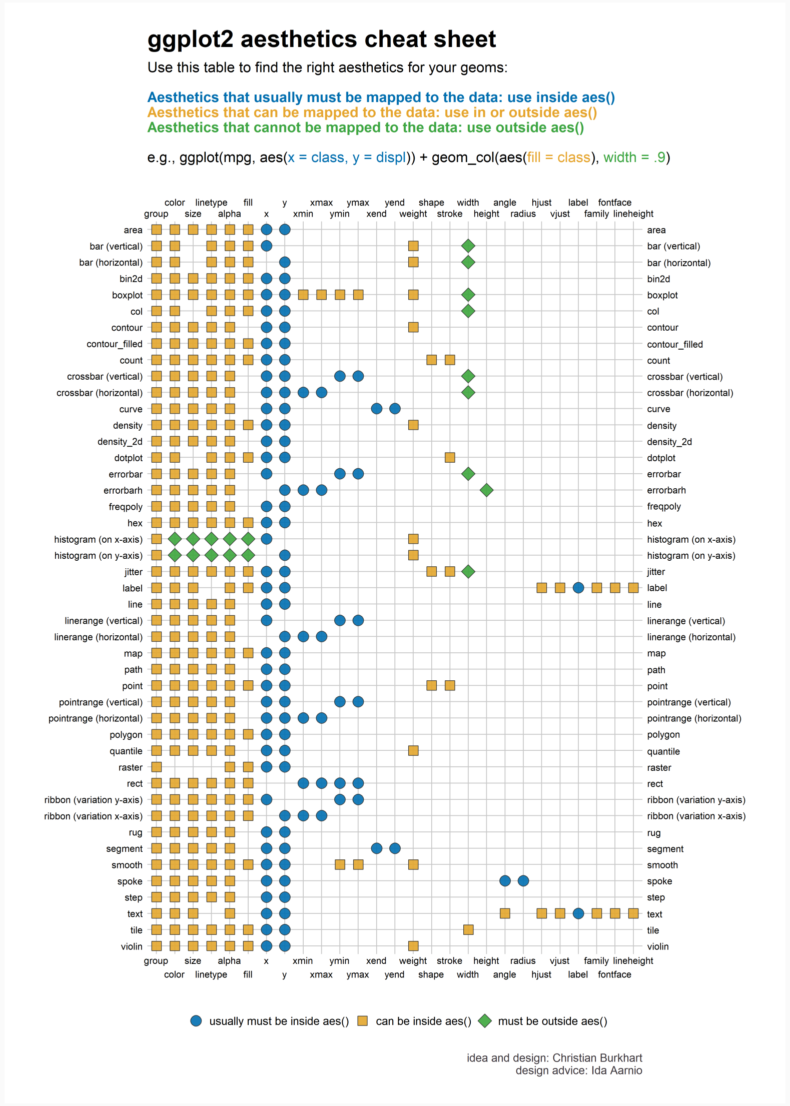


Density Plots (cont.)

```
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)

	group	color	size	linetype	alpha	fill	x	y	xmin	xmax	ymin	ymax	xend	yend	weight	shape	stroke	width	height	angle	radius	hjust	vjust	label	family	fontface	lineheight
area	■	■	■	■	■	■	●	●																			
bar (vertical)	■	■		■	■	■	●								■			◆									
bar (horizontal)	■	■		■	■	■		●							■			◆									
bin2d	■	■	■	■	■	■	●	●																			
boxplot	■	■	■	■	■	■	●	●	■	■	■	■			■			◆									
col	■	■		■	■	■	●	●										◆									
contour	■	■	■	■	■		●	●							■												
contour_filled	■	■	■	■	■	■	●	●																			
count	■	■	■	■	■	■	●	●								■	■										
crossbar (vertical)	■	■	■	■	■		●	●			●	●						◆									
crossbar (horizontal)	■	■	■	■	■		●	●	●	●								◆									
curve	■	■	■	■	■		●	●					●	●													
density	■	■	■	■	■	■	●	●							■												
density_2d	■	■	■	■	■		●	●																			
dotplot	■	■		■	■	■	●	●									■										
errorbar	■	■	■	■	■		●				●	●						◆									
errorbarh	■	■	■	■	■			●	●	●									◆								
freqpoly	■	■	■	■	■		●	●																			
hex	■	■	■	■	■	■	●	●																			
histogram (on x-axis)	■	◆	◆	◆	◆	◆	●								■												
histogram (on y-axis)	■	◆	◆	◆	◆	◆		●							■												
jitter	■	■	■	■	■	■	●	●								■	■	◆									
label	■	■	■		■	■	●	●														■	■	●	■	■	■
line	■	■	■	■	■		●	●																			
linerange (vertical)	■	■	■	■	■		●				●	●															
linerange (horizontal)	■	■	■	■	■			●	●	●																	
map	■	■	■	■	■	■	●	●																			
path	■	■	■	■	■		●	●																			
point	■	■	■	■	■	■	●	●								■	■										
pointrange (vertical)	■	■	■	■	■		●	●			●	●															
pointrange (horizontal)	■	■	■	■	■		●	●	●	●																	
polygon	■	■	■	■	■	■	●	●																			
quantile	■	■	■	■	■		●	●							■												
raster	■				■	■	●	●																			
rect	■	■	■	■	■	■			●	●	●	●															
ribbon (variation y-axis)	■	■	■	■	■	■	●				●	●															
ribbon (variation x-axis)	■	■	■	■	■	■		●	●	●																	
rug	■	■	■	■	■		●	●																			
segment	■	■	■	■	■		●	●					●	●													
smooth	■	■	■	■	■	■	●	●			■	■			■												
spoke	■	■	■	■	■		●	●												●	●						
step	■	■	■	■	■		●	●																			
text	■	■	■		■		●	●												■		■	■	●	■	■	■
tile	■	■	■	■	■	■	●	●										■									
violin	■	■	■	■	■	■	●	●							■												

● usually must be inside aes() ■ can be inside aes() ◆ must be outside aes()

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).

```r
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."))
```

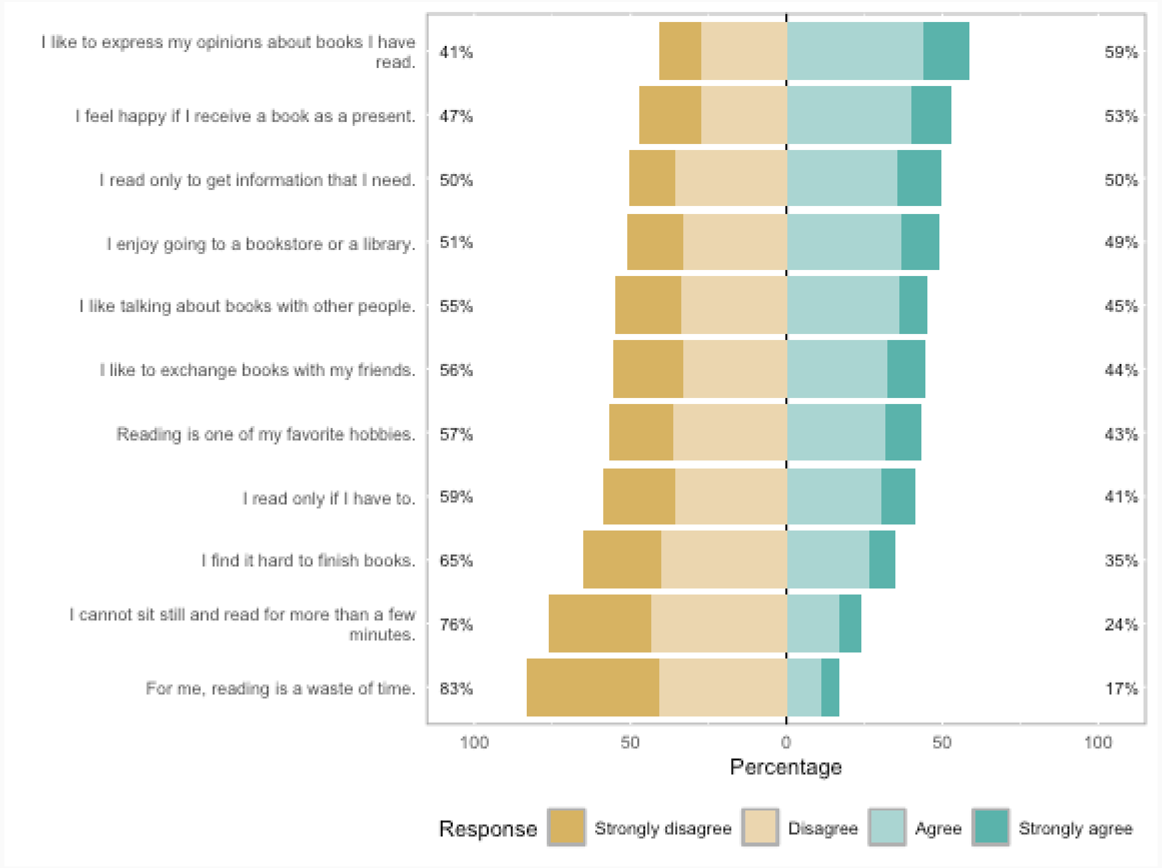
likert R Package

```r
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
```

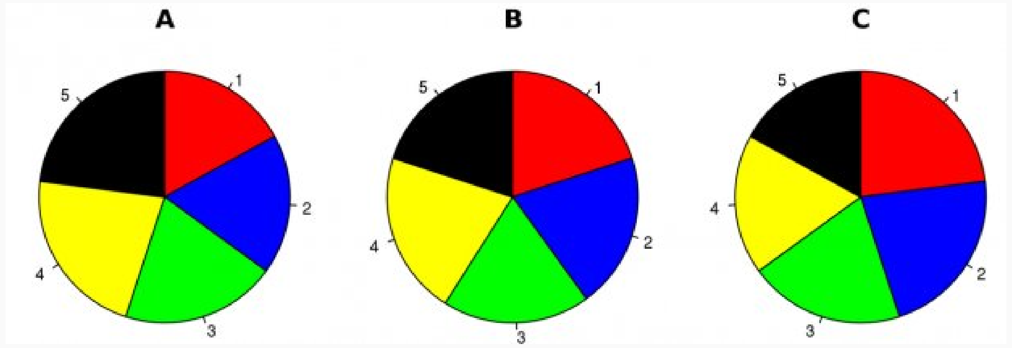
`likert` Plots

```
plot(l24)
```



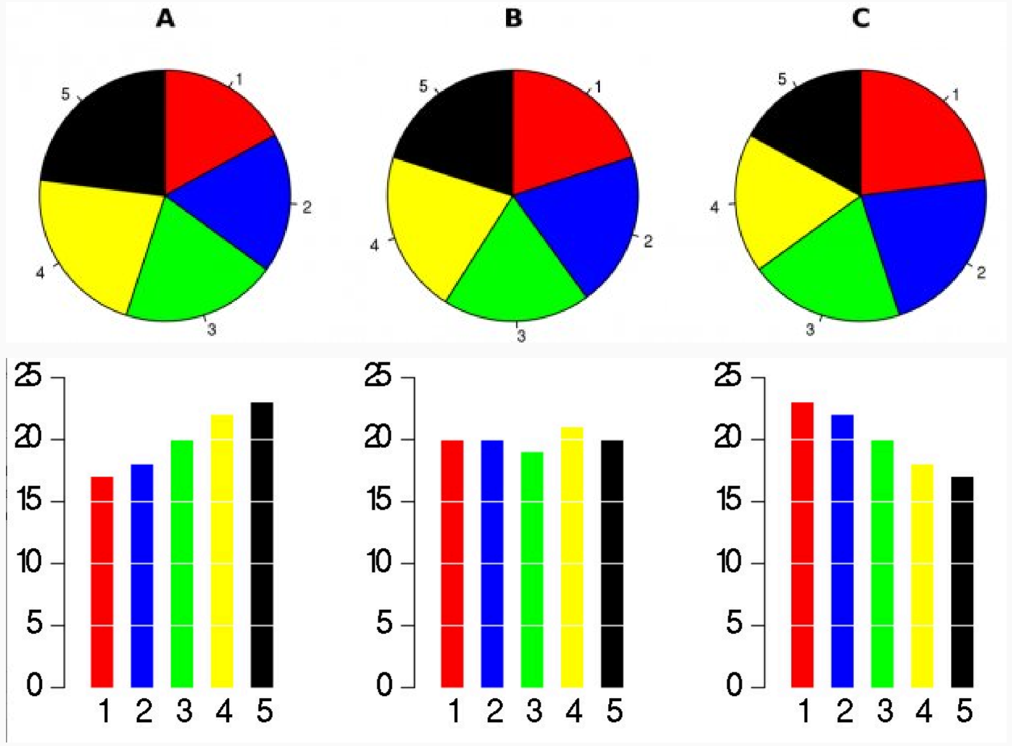
Pie Charts

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/ESBAdHRhzT65fW6c6