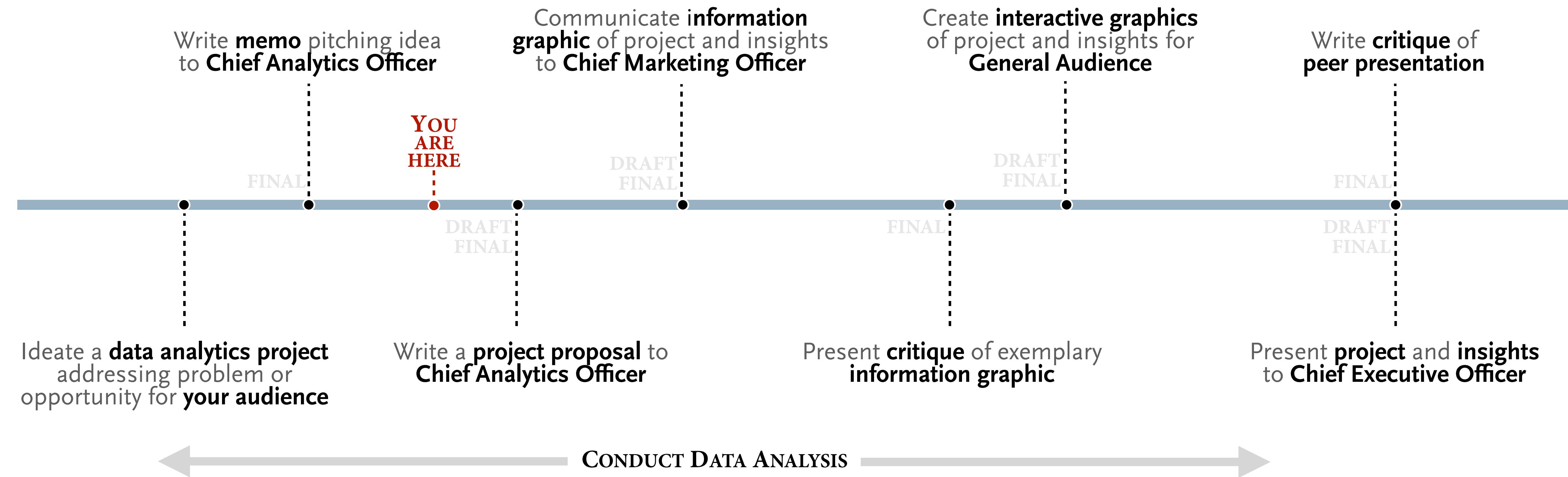


Storytelling with data

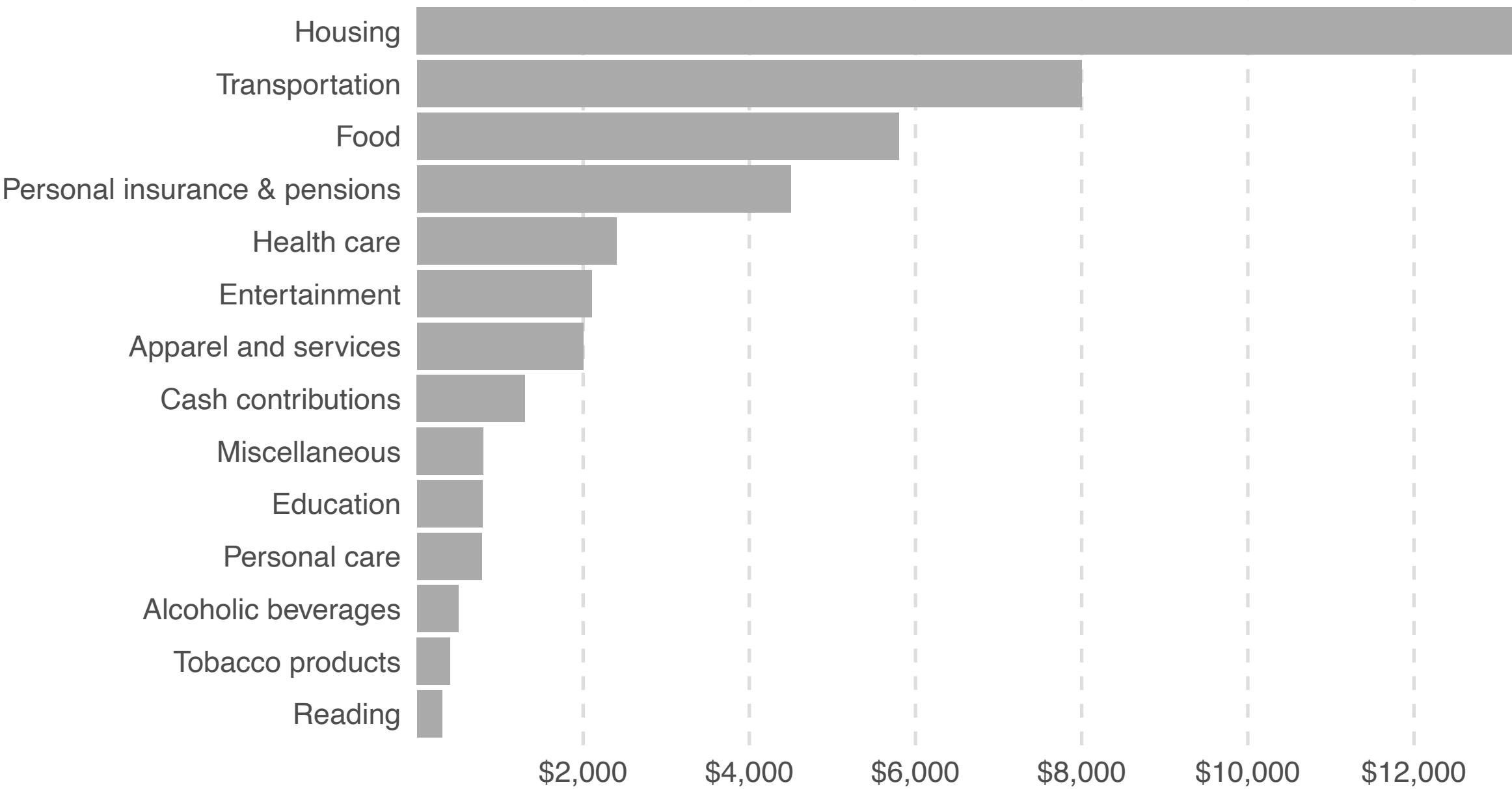
05 | visual design, data encodings, perceptual psychology

course overview | main course deliverables



Why show data graphically?

why data graphics, graphic of a datum — effective? Conveys meaning?



While text can use different types of content structures, an abstract visualization just presents relationships between data points.

Thus, a single bar, map symbol or shape does not convey information. It only becomes meaningful by its relationship with other elements in the image—in other words, it is *polysemic*: **A data graphic acquires its meaning from comparison.**

— Koponen & Hildén, *The Data Visualization Handbook*

Fig. 3. Major categories of expenditures, descending dollar value, 2002 U.S. Consumer Expenditure Survey

why data graphics, graphic of a datum — effective? Conveys meaning?

Housing

While text can use different types of content structures, an abstract visualization just presents relationships between data points.

Thus, a single bar, map symbol or shape does not convey information. It only becomes meaningful by its relationship with other elements in the image—in other words, it is *polysemic*: **A data graphic acquires its meaning from comparison.**

— Koponen & Hildén, *The Data Visualization Handbook*

why data graphics, example data from Anscombe

1		2		3		4	
x	y	x	y	x	y	x	y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.10	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.10	4	5.39	19	12.50
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

why data graphics, example data from Anscombe

1		2		3		4	
x	y	x	y	x	y	x	y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.10	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.10	4	5.39	19	12.50
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

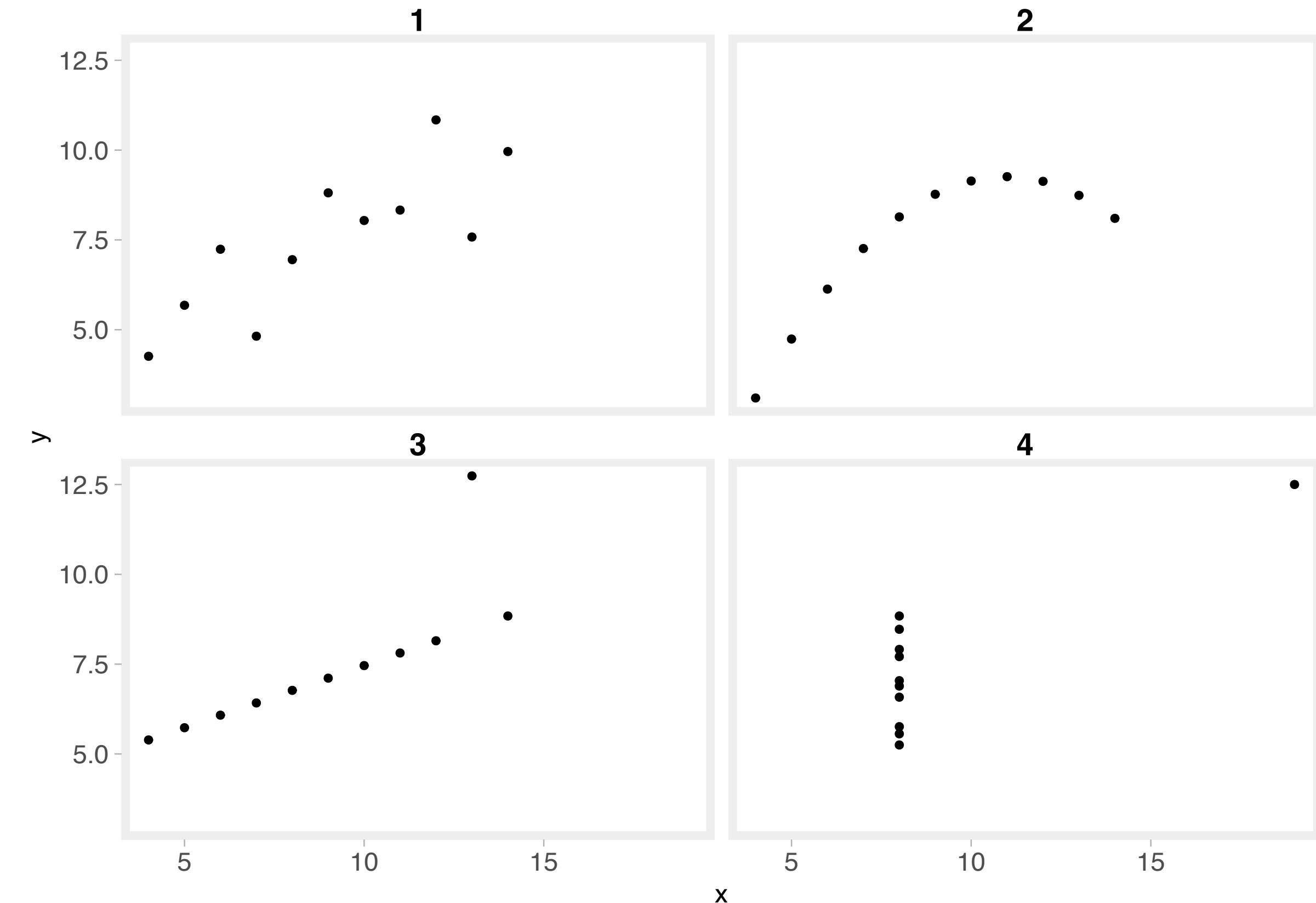
summary statistics: *are the 4 data sets the same?*

1		2		3		4		
x	y	x	y	x	y	x	y	
mean	9.00	7.50	9.00	7.50	9.00	7.50	9.00	7.50
sd	3.32	2.03	3.32	2.03	3.32	2.03	3.32	2.03
Parameter		Mean		Std Err		t-val		
Dataset 1								
(Intercept)		3.000		1.125		2.667		
x		0.500		0.118		4.241		
Dataset 2								
(Intercept)		3.001		1.125		2.667		
x		0.500		0.118		4.239		
Dataset 3								
(Intercept)		3.002		1.124		2.670		
x		0.500		0.118		4.239		
Dataset 4								
(Intercept)		3.002		1.124		2.671		
x		0.500		0.118		4.243		

why data graphics, example data from Anscombe

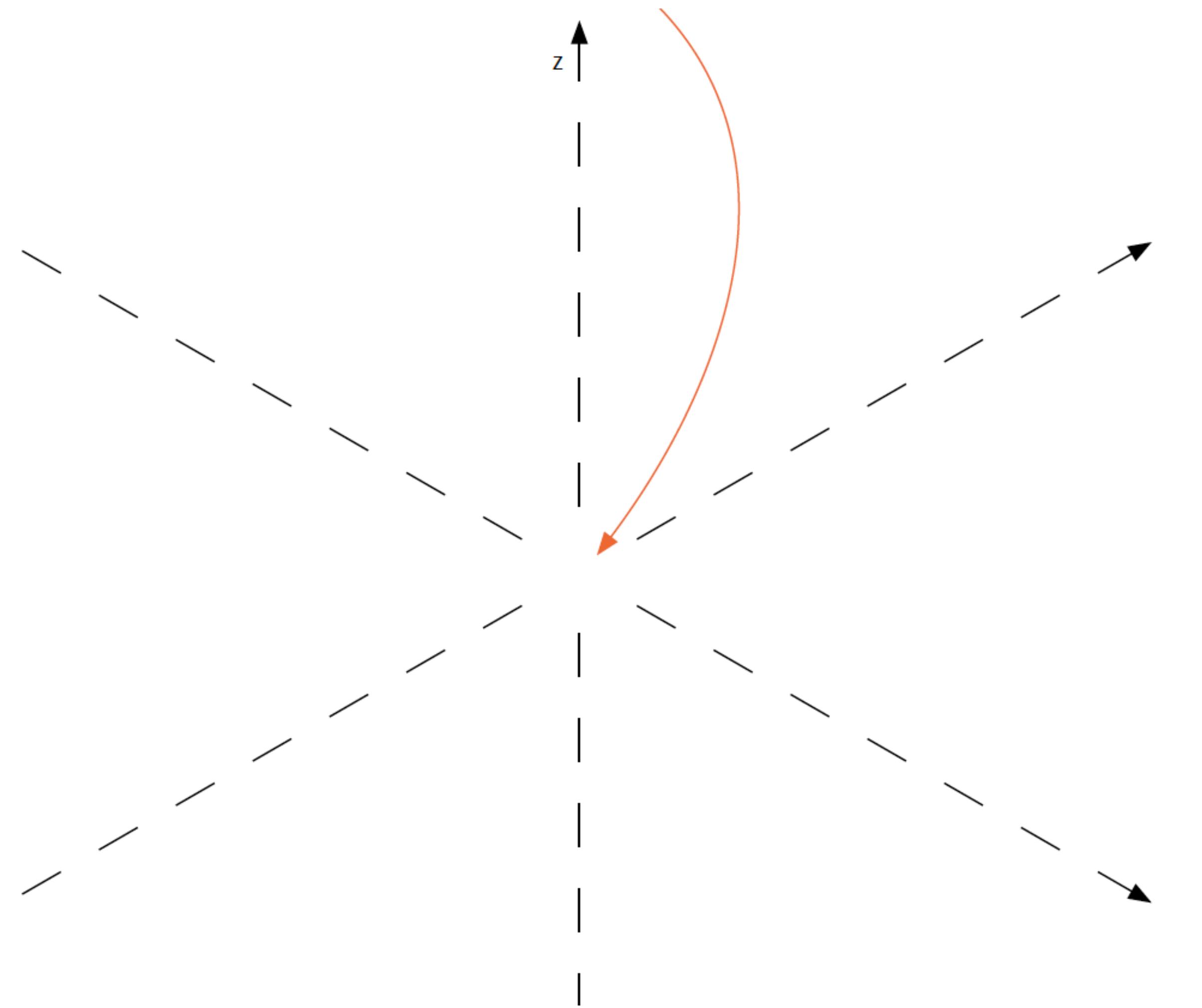
With graphics we can use our natural ability
to see patterns through visual comparison

1		2		3		4	
x	y	x	y	x	y	x	y
10	8.04	10	9.14	10	7.46	8	6.58
8	6.95	8	8.14	8	6.77	8	5.76
13	7.58	13	8.74	13	12.74	8	7.71
9	8.81	9	8.77	9	7.11	8	8.84
11	8.33	11	9.26	11	7.81	8	8.47
14	9.96	14	8.10	14	8.84	8	7.04
6	7.24	6	6.13	6	6.08	8	5.25
4	4.26	4	3.10	4	5.39	19	12.50
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

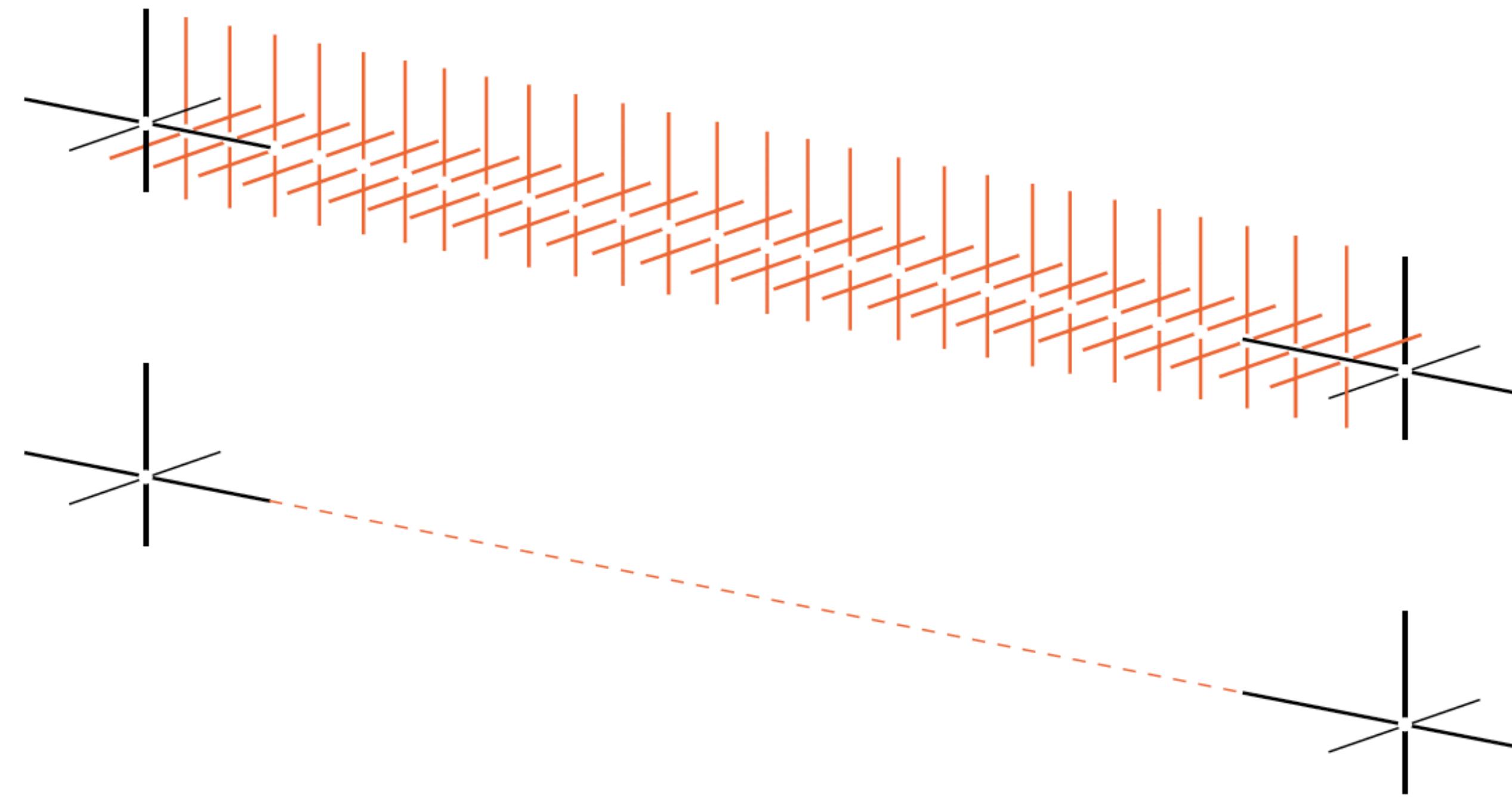


graphic design concepts

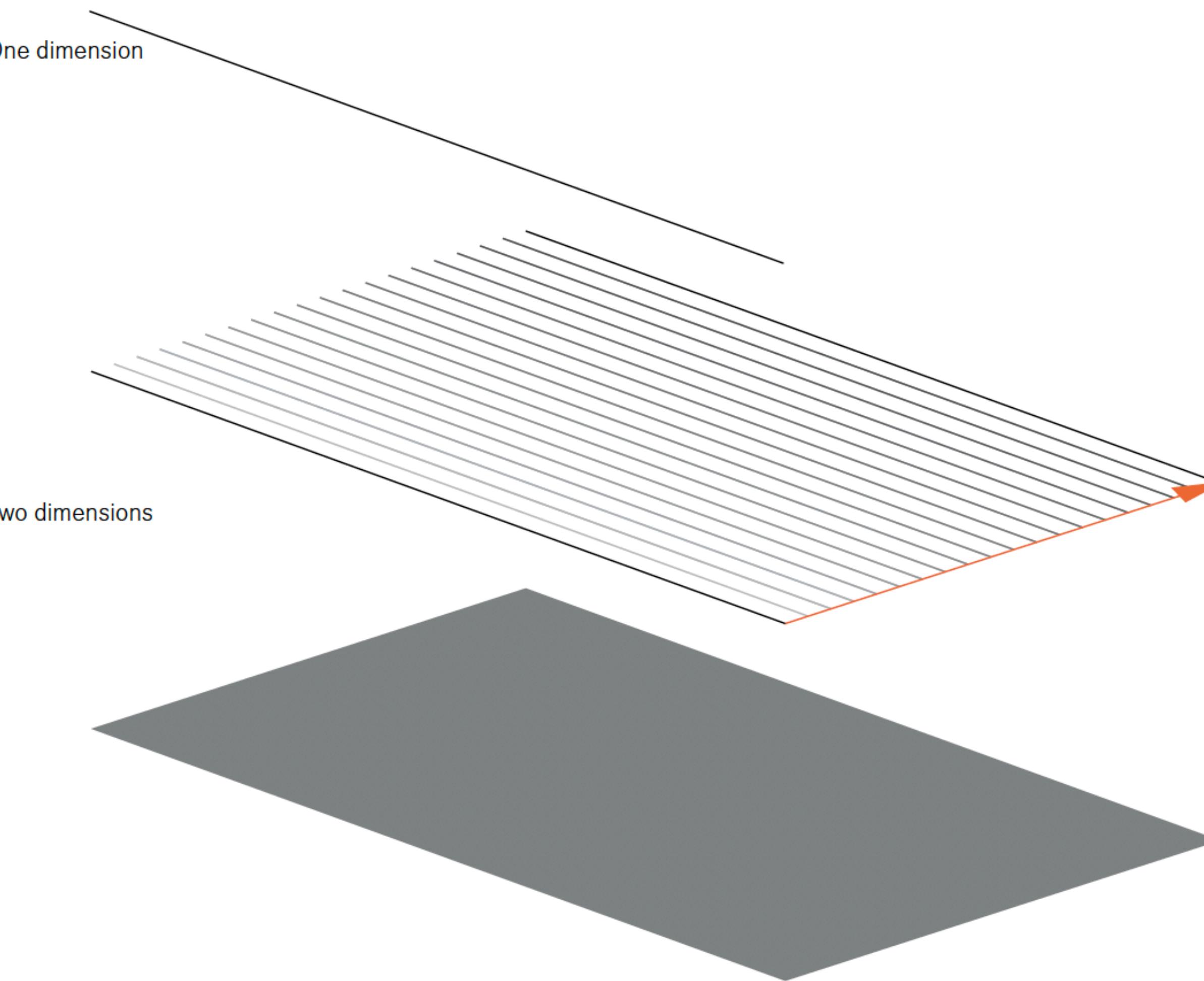
data encodings, geometry of graphical elements — point



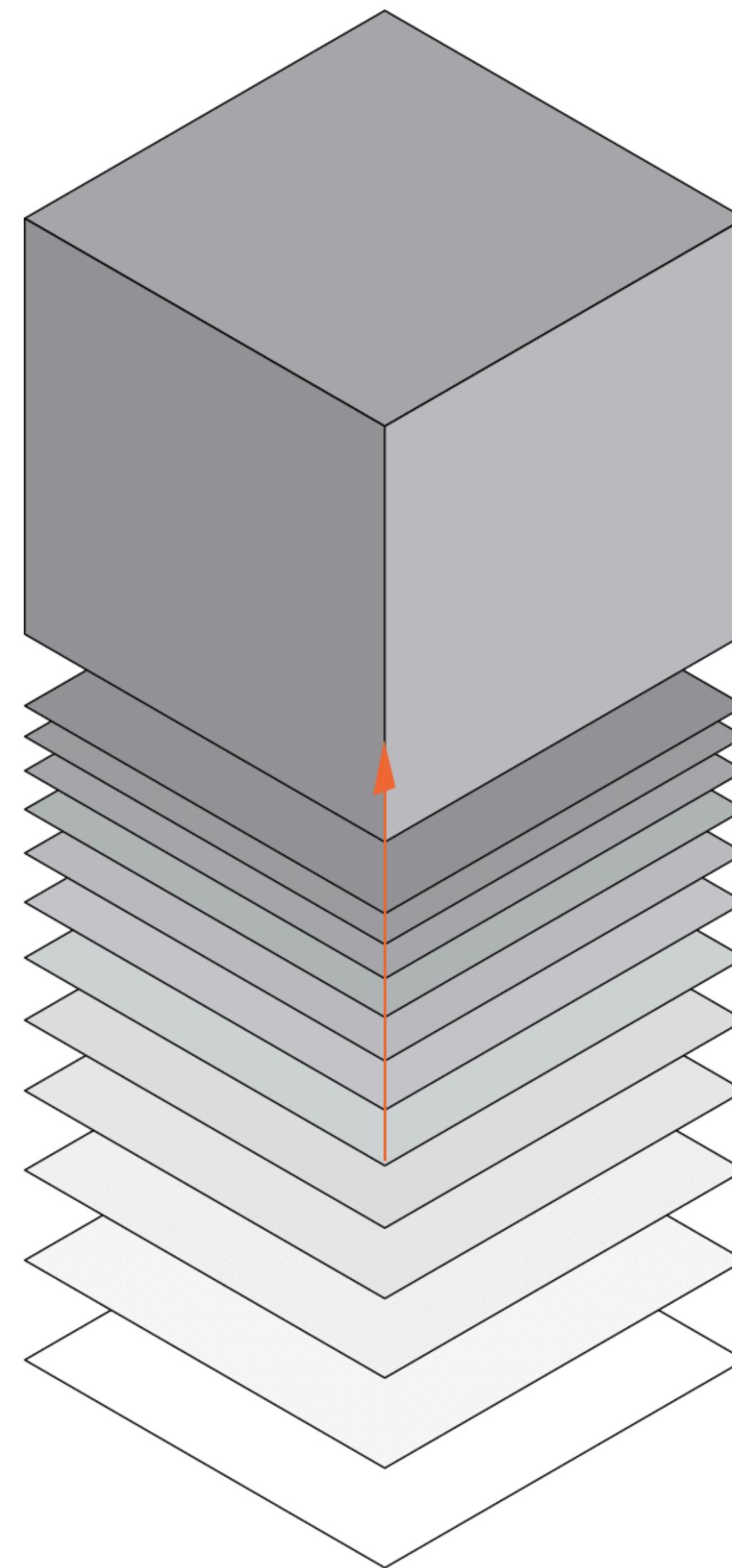
data encodings, geometry of graphical elements — line



data encodings, geometry of graphical elements — surface

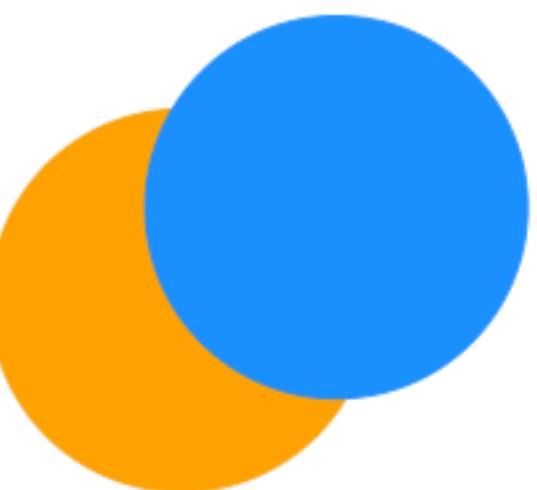


data encodings, geometry of graphical elements — volume

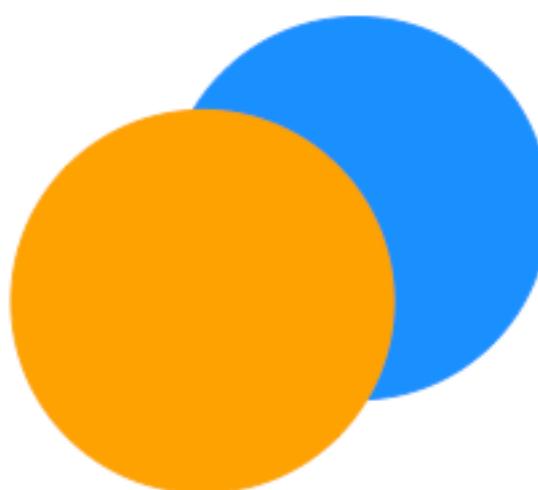


data encodings, layering — order of elements determines position towards reader and when overlapping, occlude

```
ggplot() +  
  theme_void() +  
  scale_x_continuous(limits = c(-5, 5)) +  
  scale_y_continuous(limits = c(-5, 5)) +  
  geom_point(  
    mapping = aes(  
      x = 0,  
      y = 0),  
    size = 50,  
    color = "orange") +  
  geom_point(  
    mapping = aes(  
      x = 1,  
      y = 1),  
    size = 50,  
    color = "dodgerblue")
```

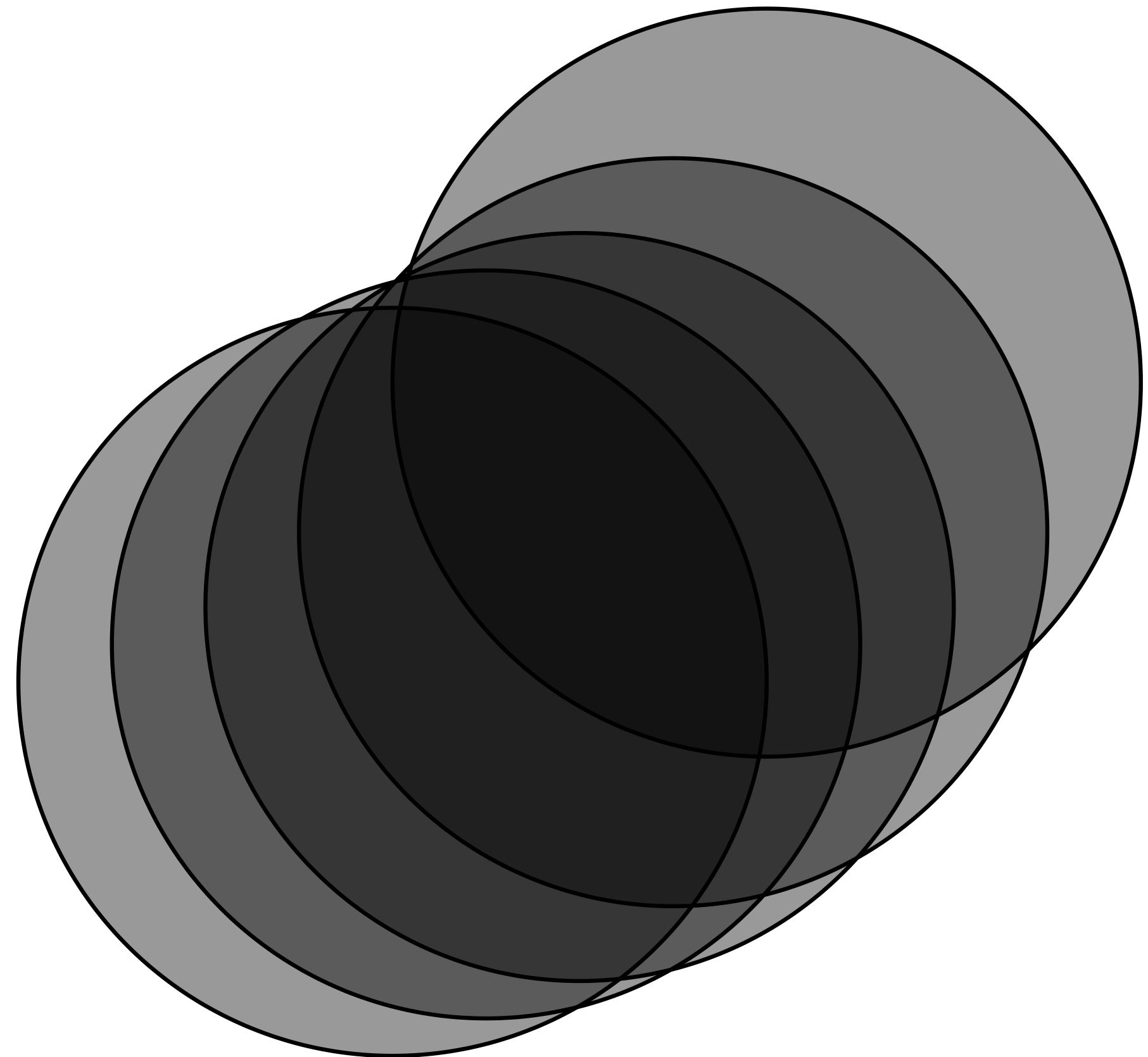


```
ggplot() +  
  theme_void() +  
  scale_x_continuous(limits = c(-5, 5)) +  
  scale_y_continuous(limits = c(-5, 5)) +  
  geom_point(  
    mapping = aes(  
      x = 1,  
      y = 1),  
    size = 50,  
    color = "dodgerblue") +  
  geom_point(  
    mapping = aes(  
      x = 0,  
      y = 0),  
    size = 50,  
    color = "orange")
```



data encodings, layering — transparency (alpha) of monochromes can help us reason about the density of overlapping shapes

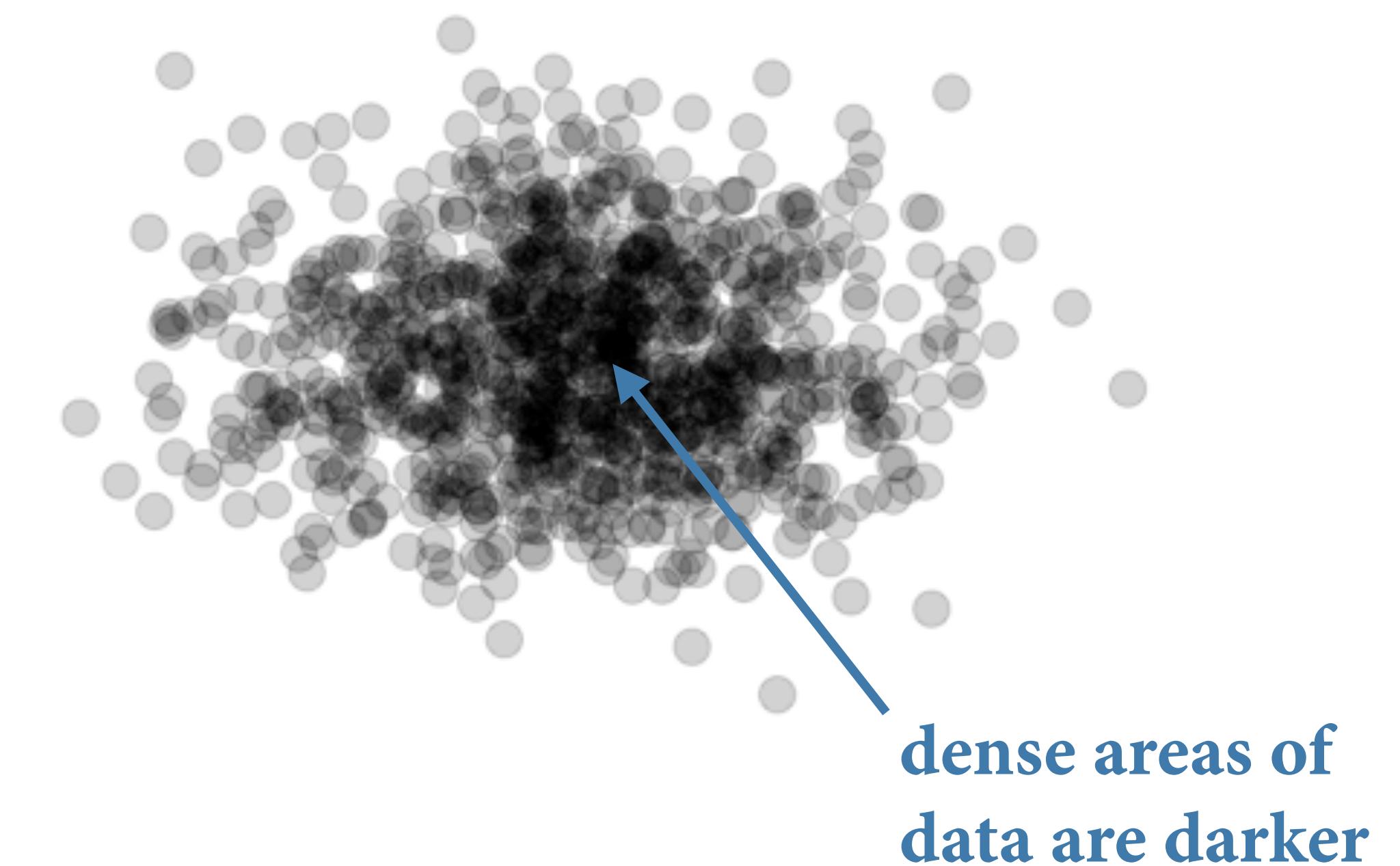
```
ggplot() +  
  theme_void() +  
  coord_equal() +  
  ggforce::geom_circle(  
    mapping = aes(  
      x0 = seq(from = 0, to = 1, length.out = 5),  
      y0 = c(0, .1, .2, .4, .8),  
      r = 1),  
    fill = "#000000",  
    alpha = 0.4)
```



data encodings, layering — transparency (alpha) of monochromes can help us reason about the density of overlapping shapes

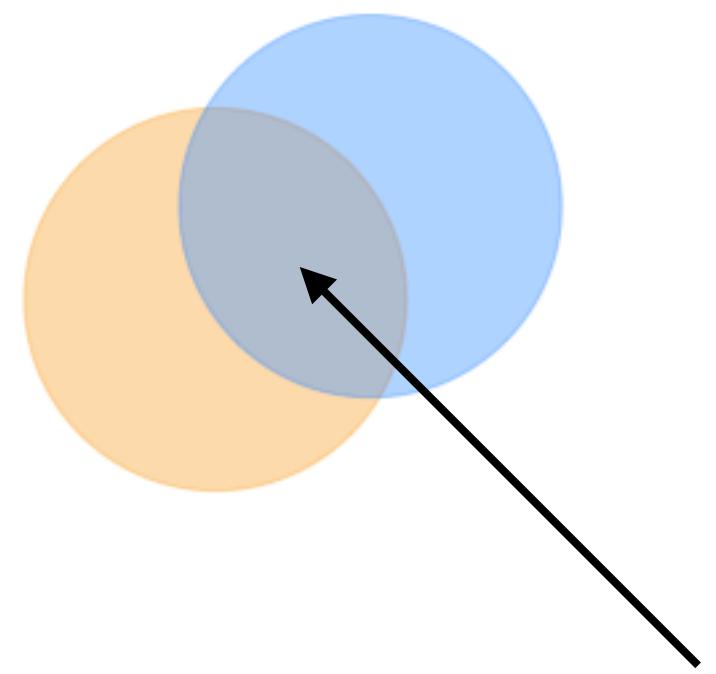
```
x <- rnorm(1000)
y <- rnorm(1000)

ggplot() +
  theme_void() +
  scale_x_continuous(limits = c(-5, 5)) +
  scale_y_continuous(limits = c(-5, 5)) +
  geom_point(
    mapping = aes(
      x = x,
      y = y),
    size = 4,
    color = "black",
    alpha = 0.2)
```



data encodings, layering — data encoded in *semi-transparent hues*, if overlapping, are affected by transparency!

```
ggplot() +  
  theme_void() +  
  scale_x_continuous(limits = c(-5, 5)) +  
  scale_y_continuous(limits = c(-5, 5)) +  
  geom_point(  
    mapping = aes(  
      x = 0,  
      y = 0),  
    size = 50,  
    color = "orange",  
    alpha = 0.4) +  
  geom_point(  
    mapping = aes(  
      x = 1,  
      y = 1),  
    size = 50,  
    color = "dodgerblue",  
    alpha = 0.4)
```

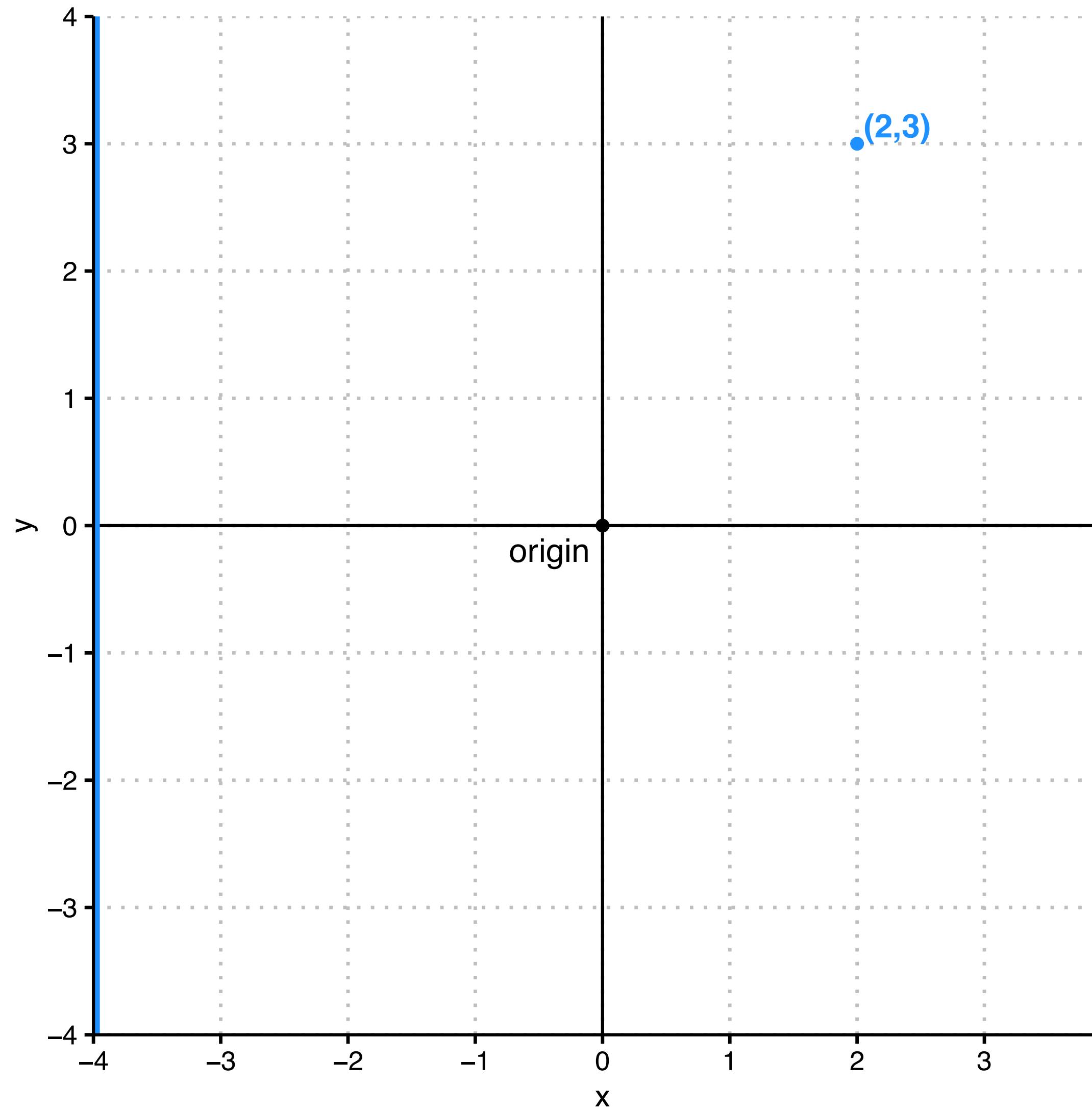


I didn't encode
data with *this color*!?

graphs — coordinate systems and scales

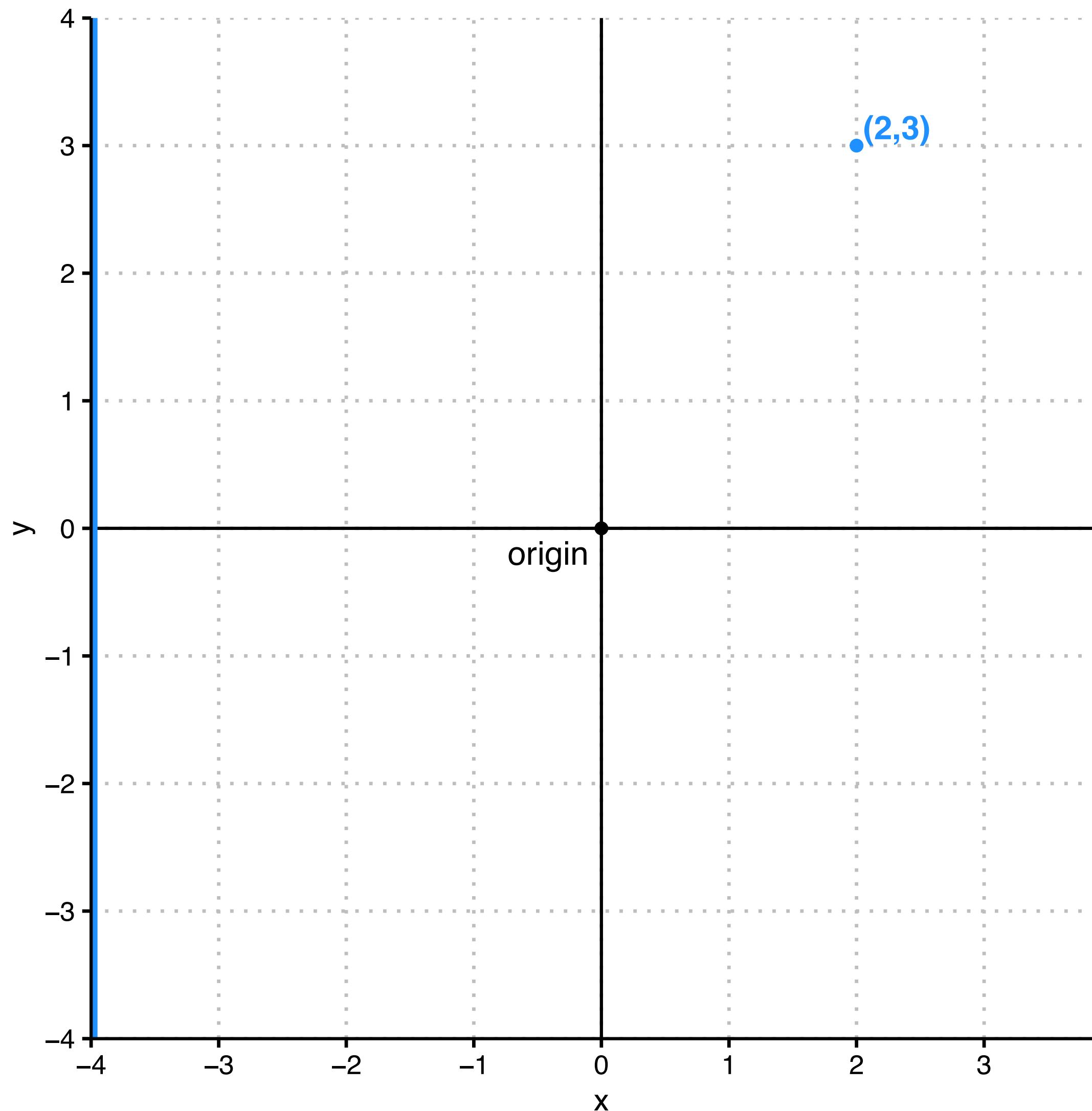
coordinates and scales, *two-dimensional Cartesian* coordinates — x and y axes run orthogonally to each other, and data values placed along linear axes

cartesian coordinates

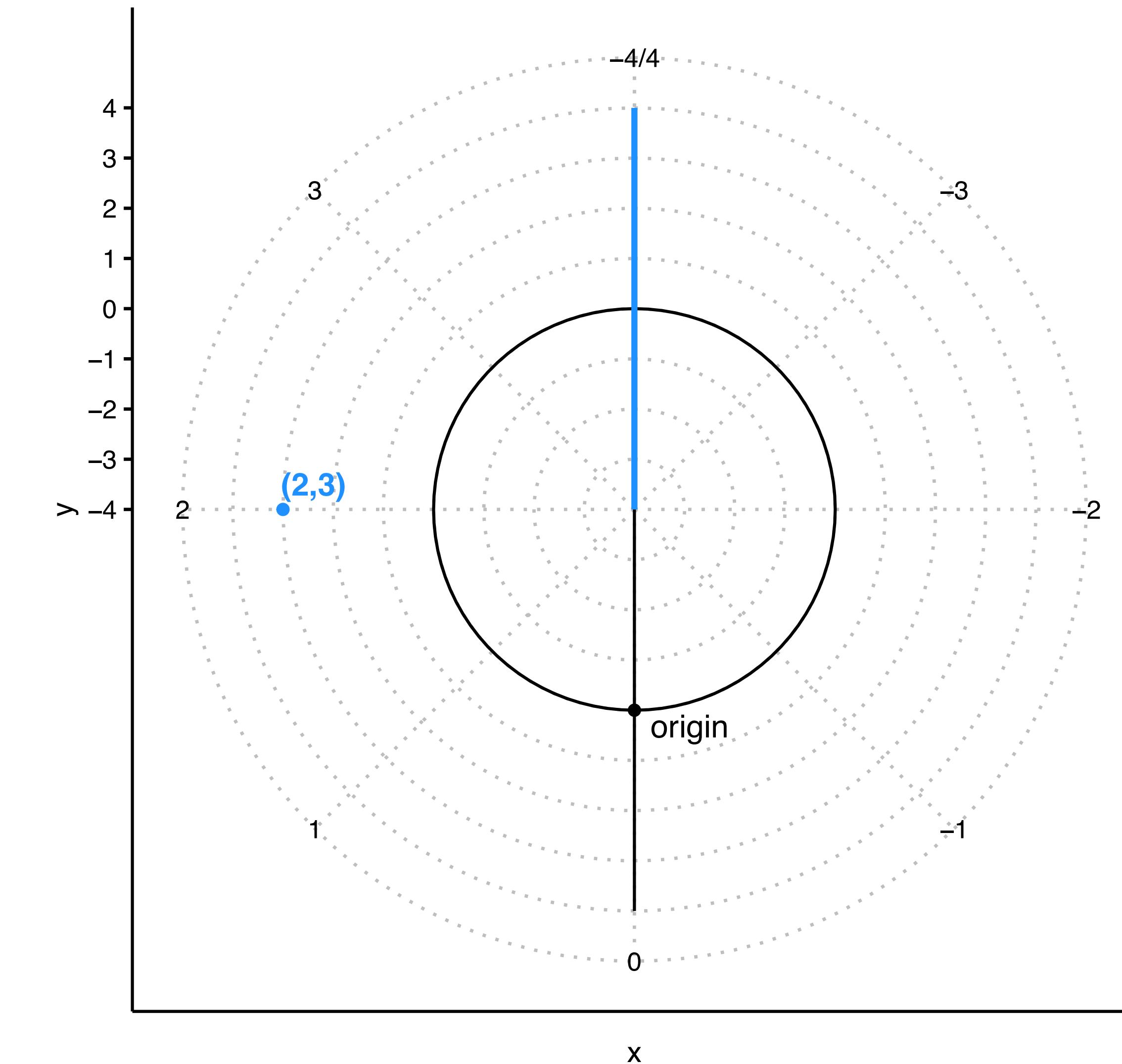


coordinates and scales, *other* coordinate systems are sometimes more effective in conveying information

cartesian coordinates

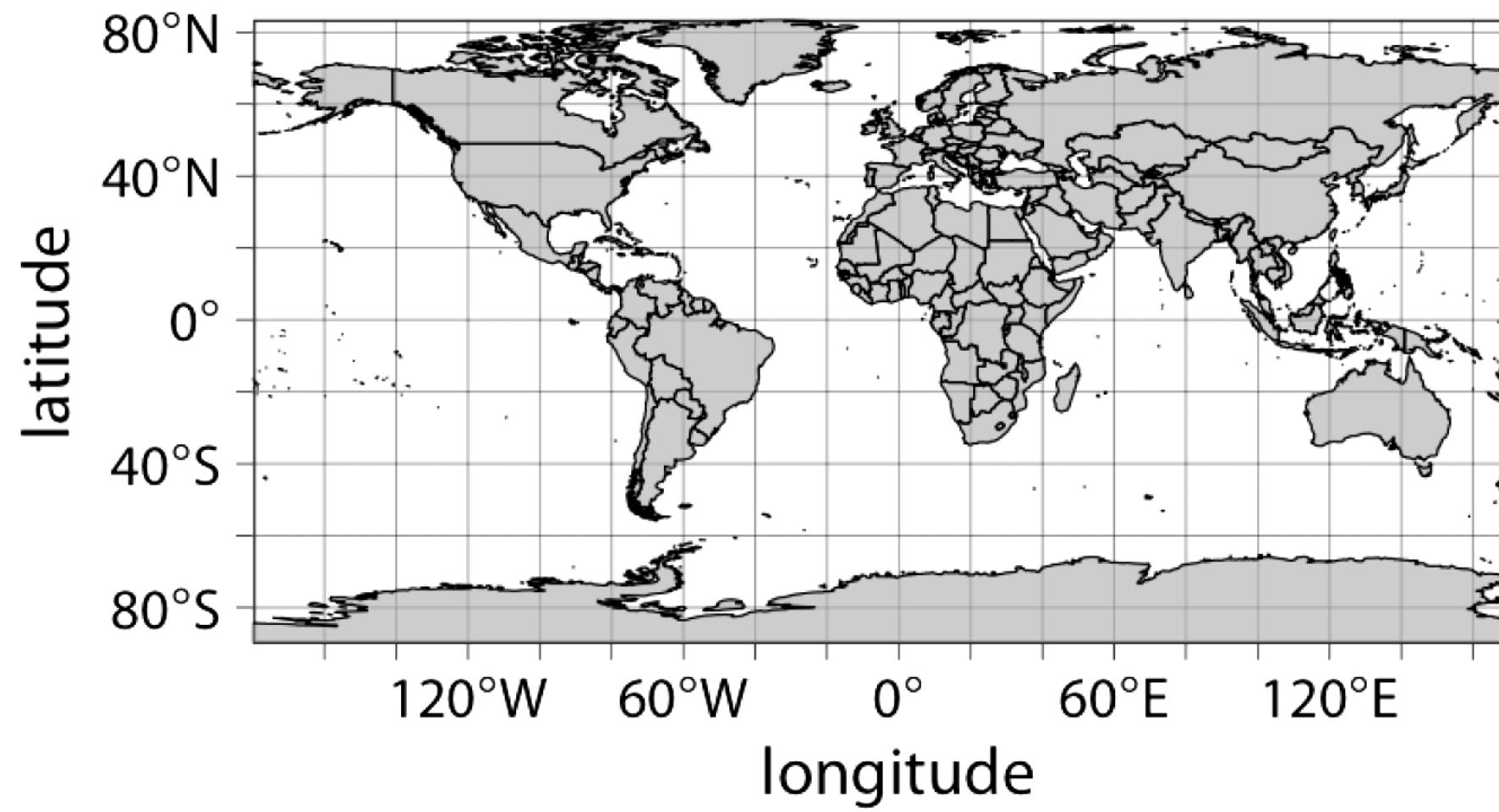


polar coordinates

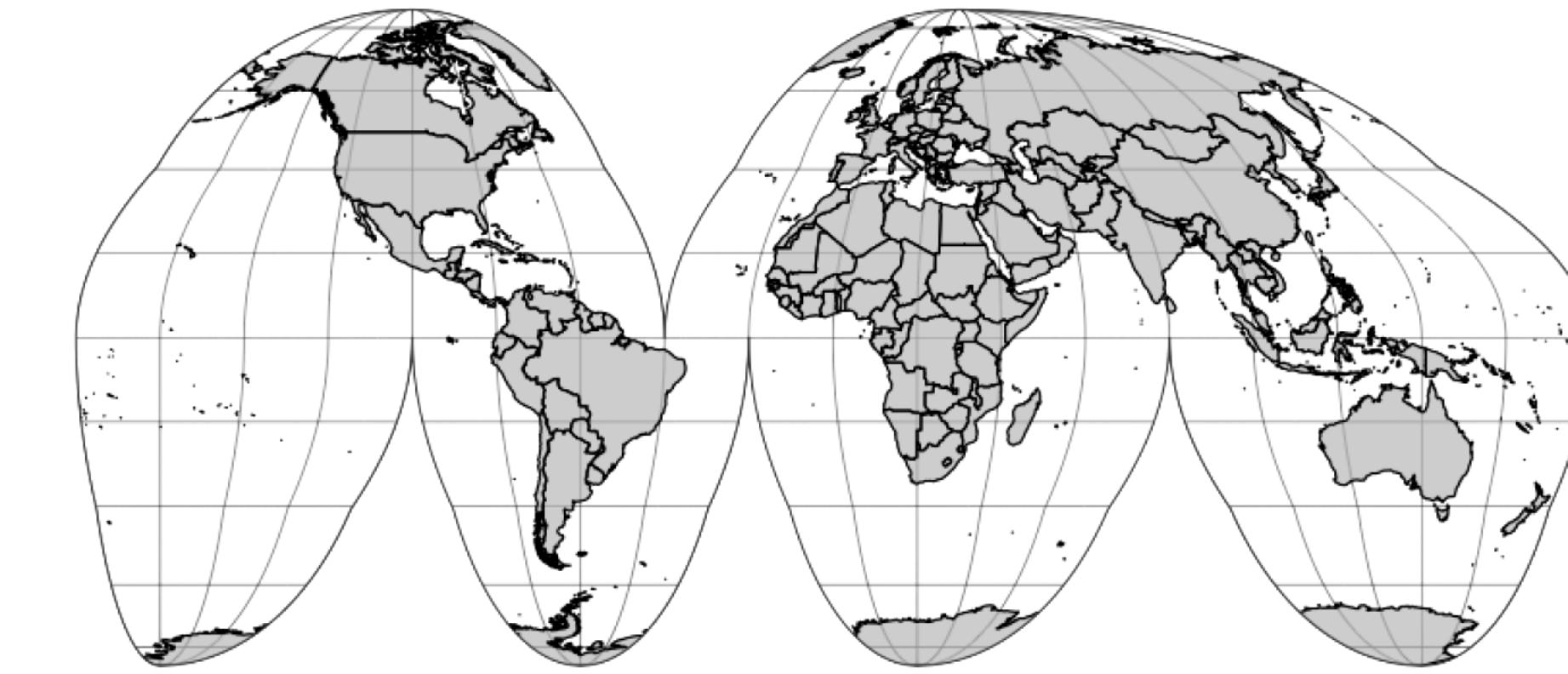


coordinates and scales, *another example*, projecting spherical surface to a plane

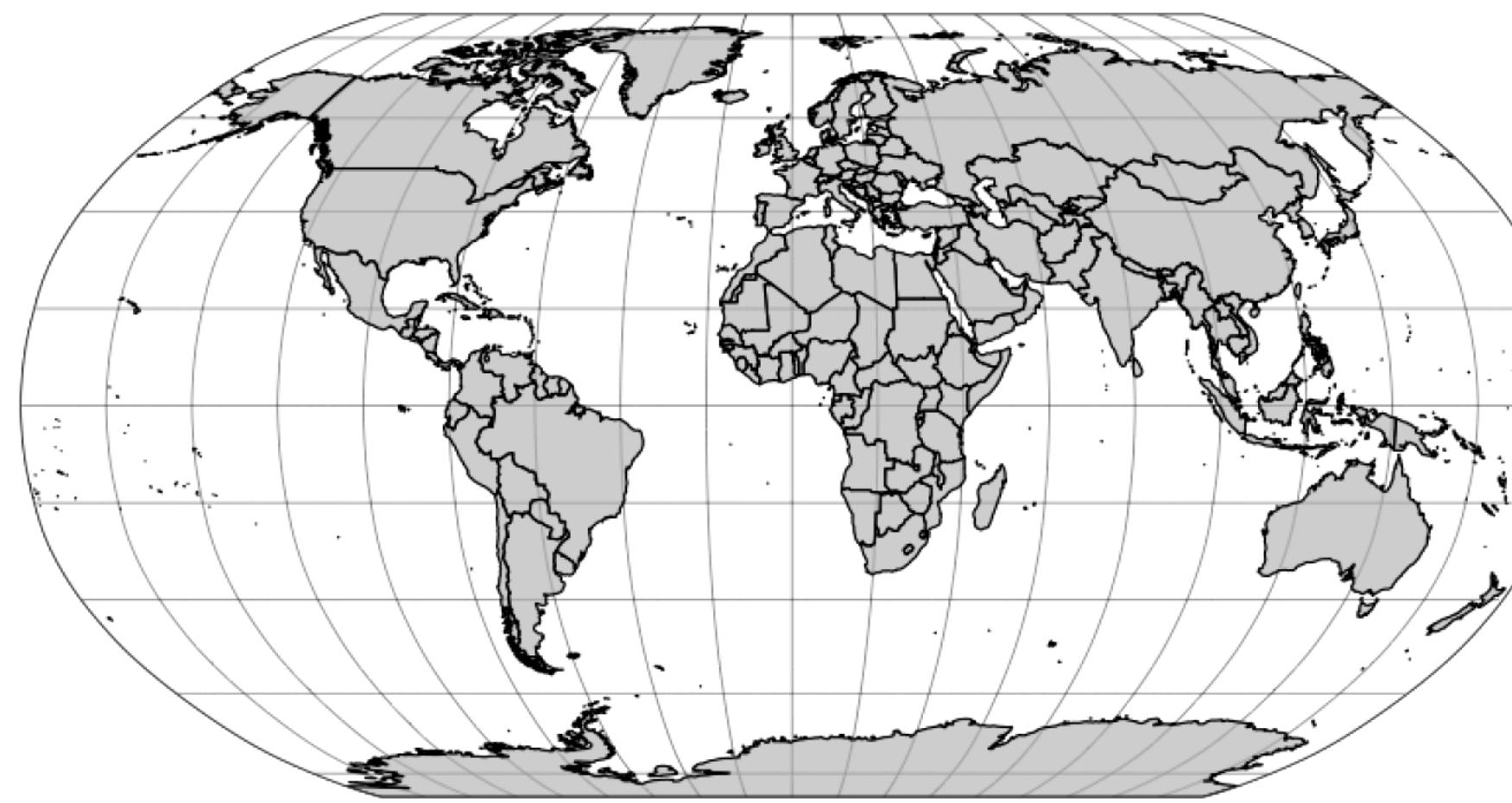
Cartesian longitude and latitude



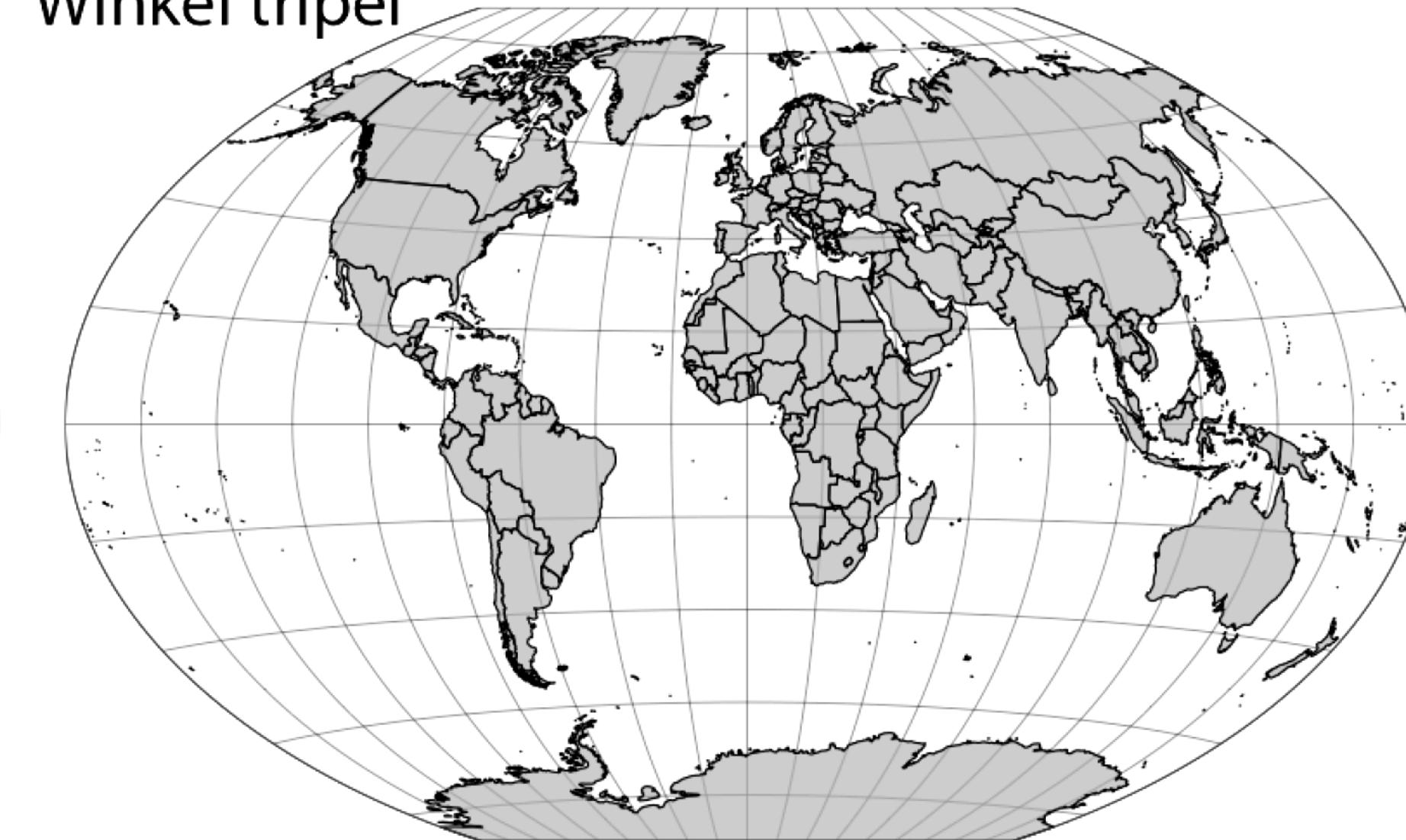
Interrupted Goode homolosine



Robinson

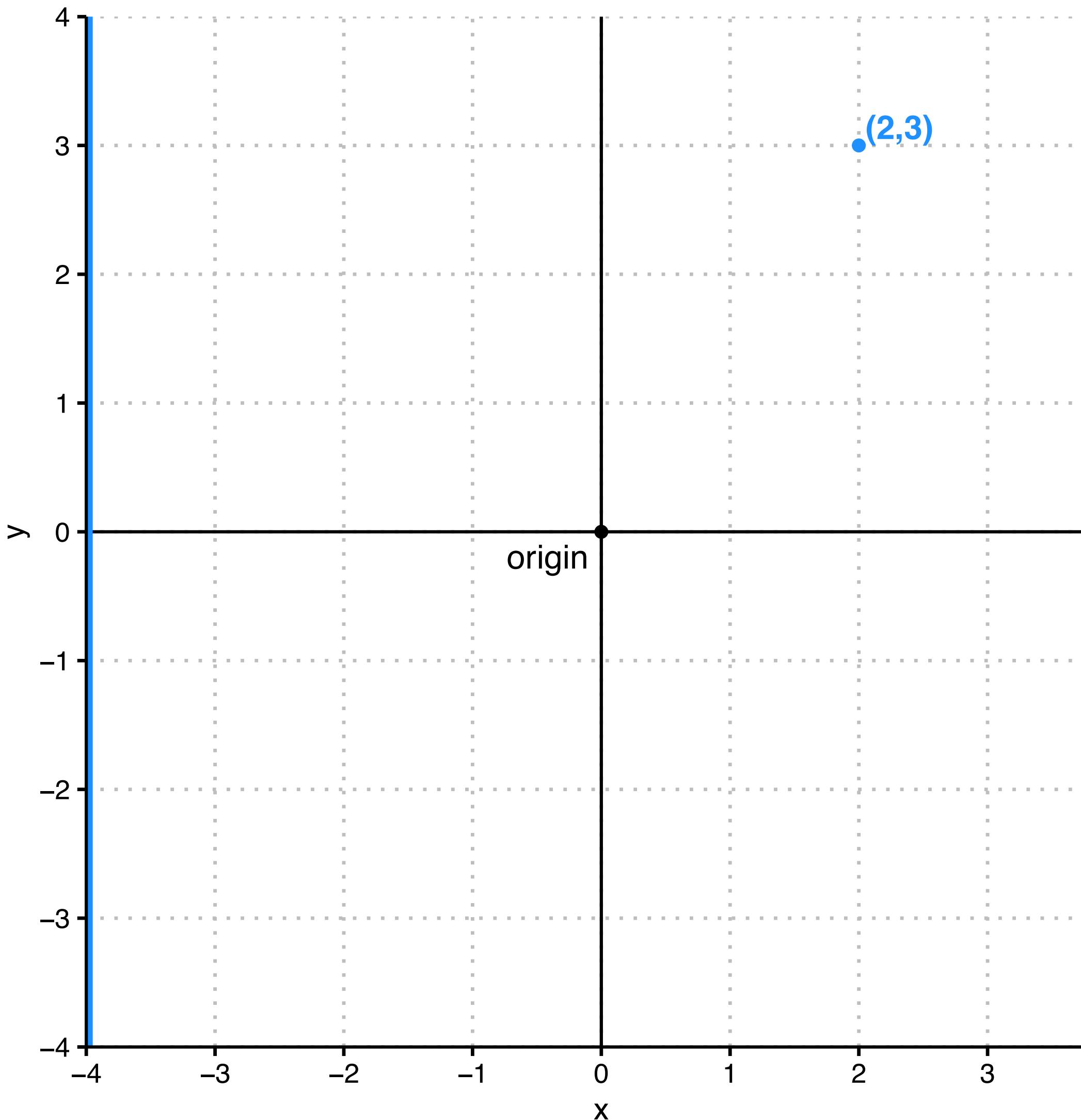


Winkel tripel

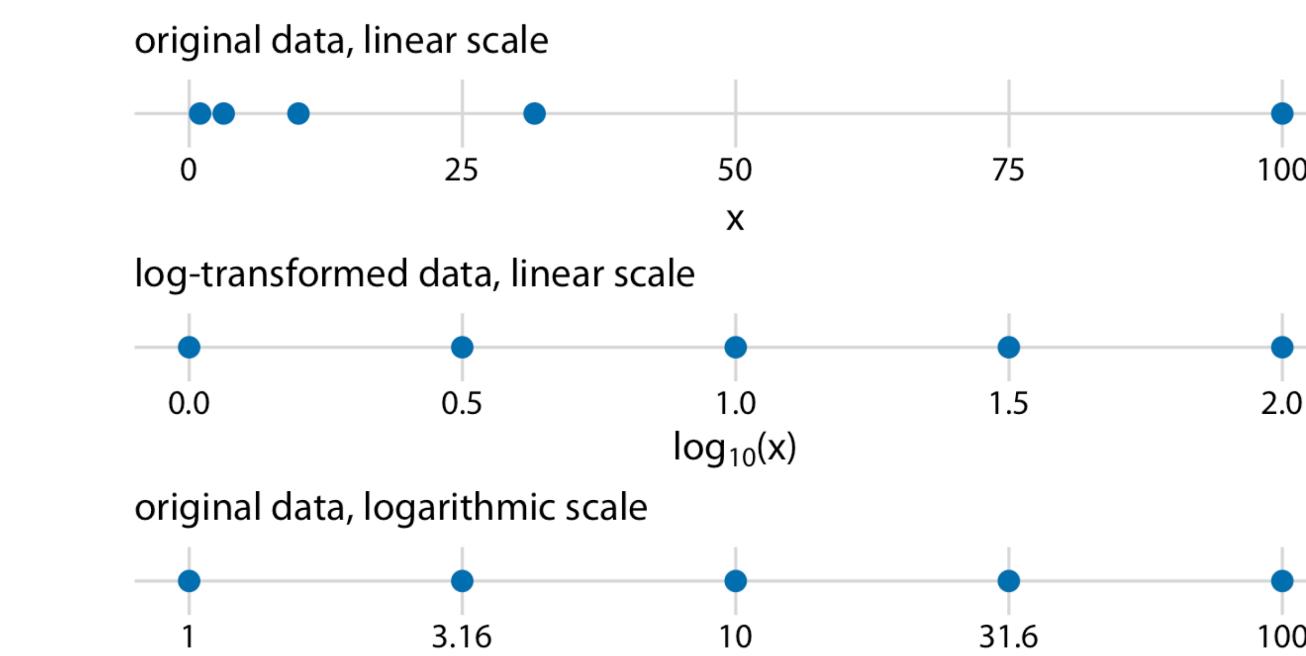


coordinates and scales, as with choosing coordinates, we can *transform scales for data or axes* for better understanding

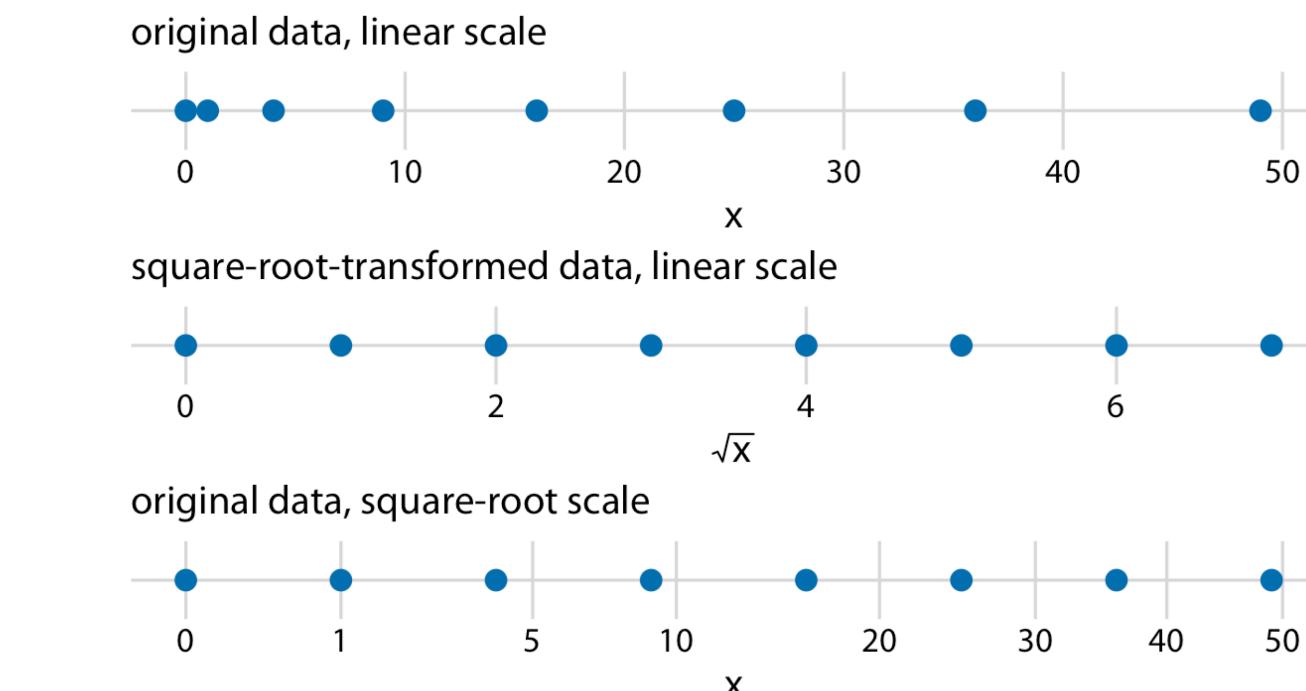
linear scales on cartesian coordinates



example — log transforms

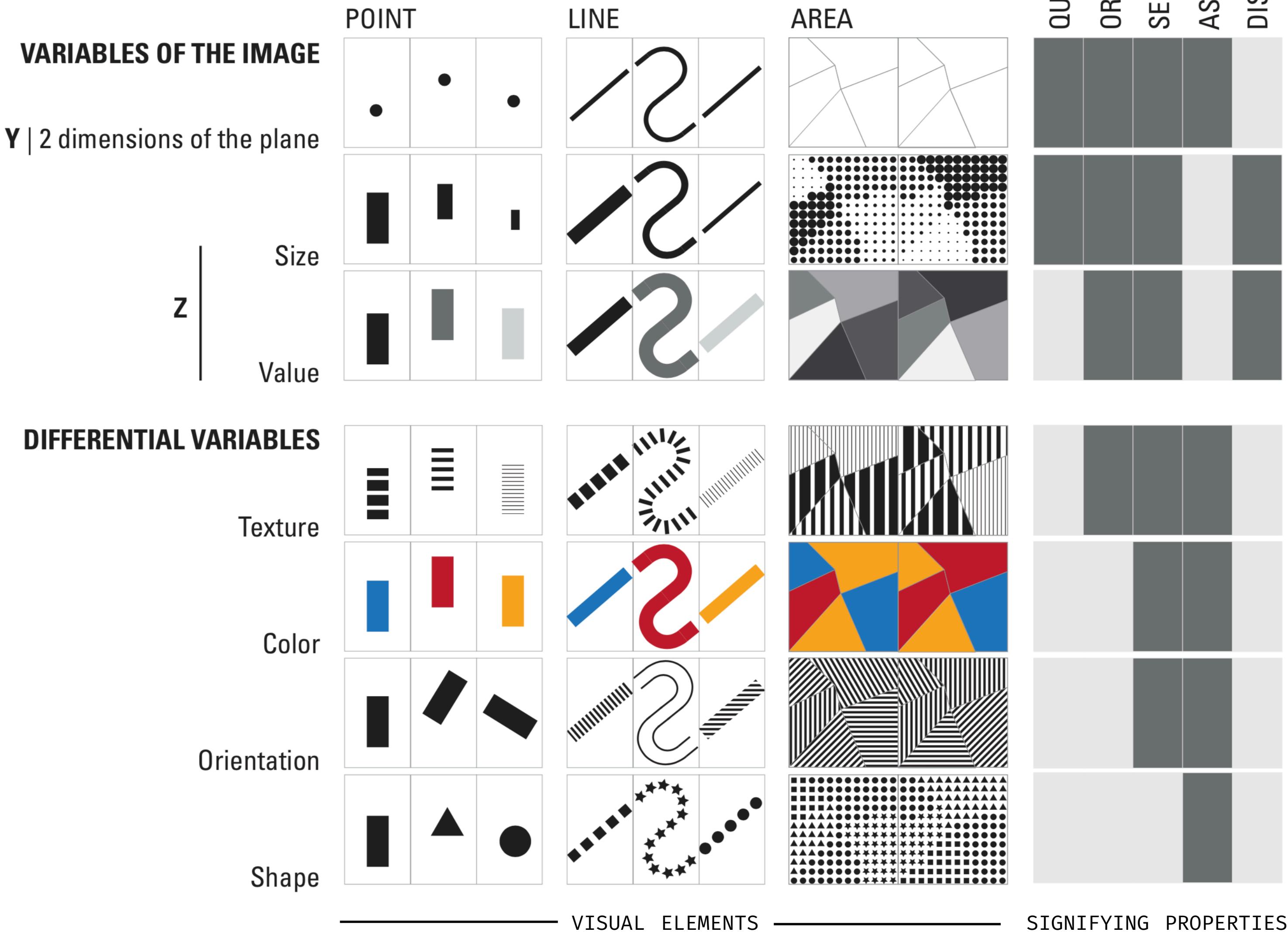


example — square-root transforms



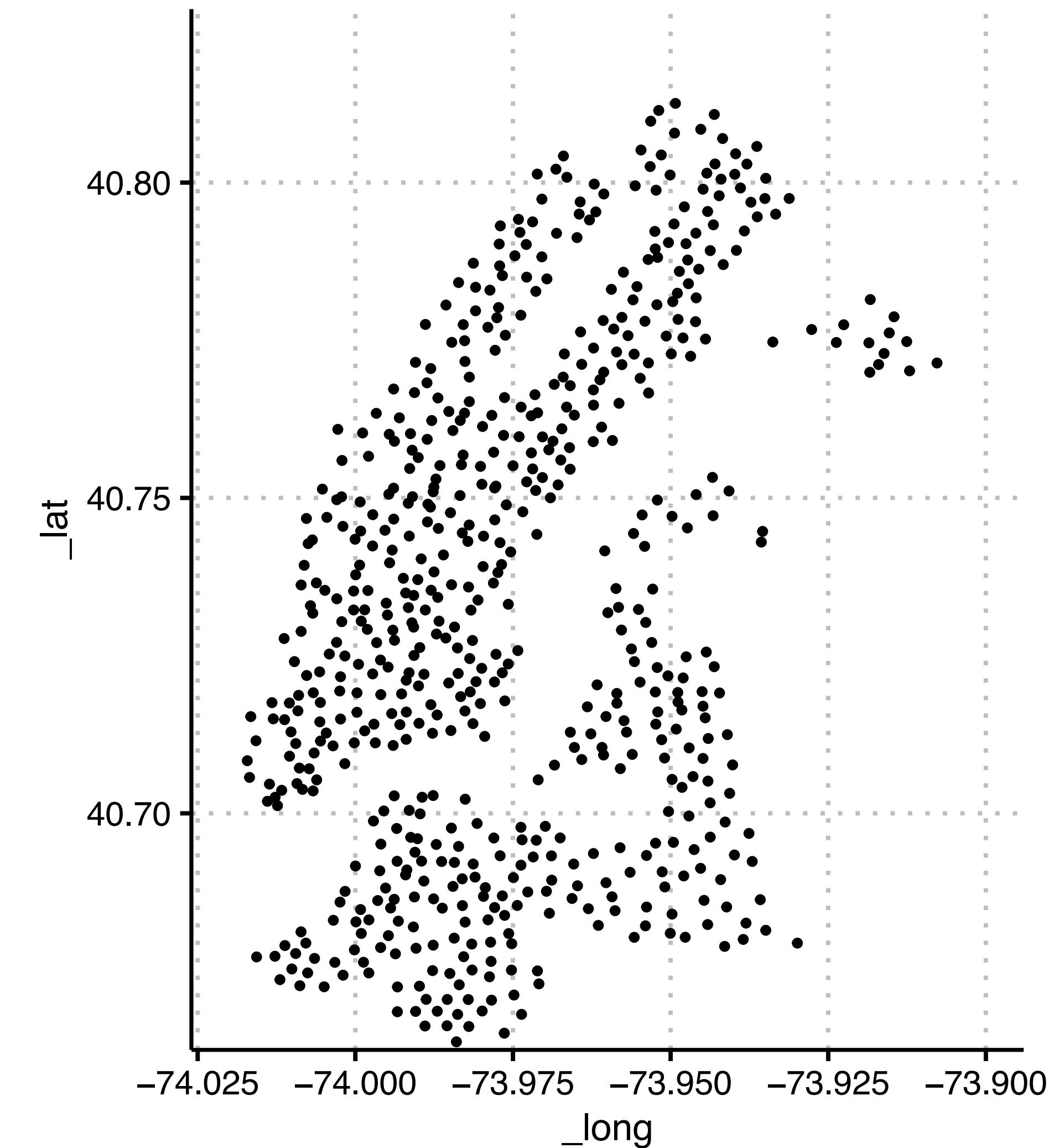
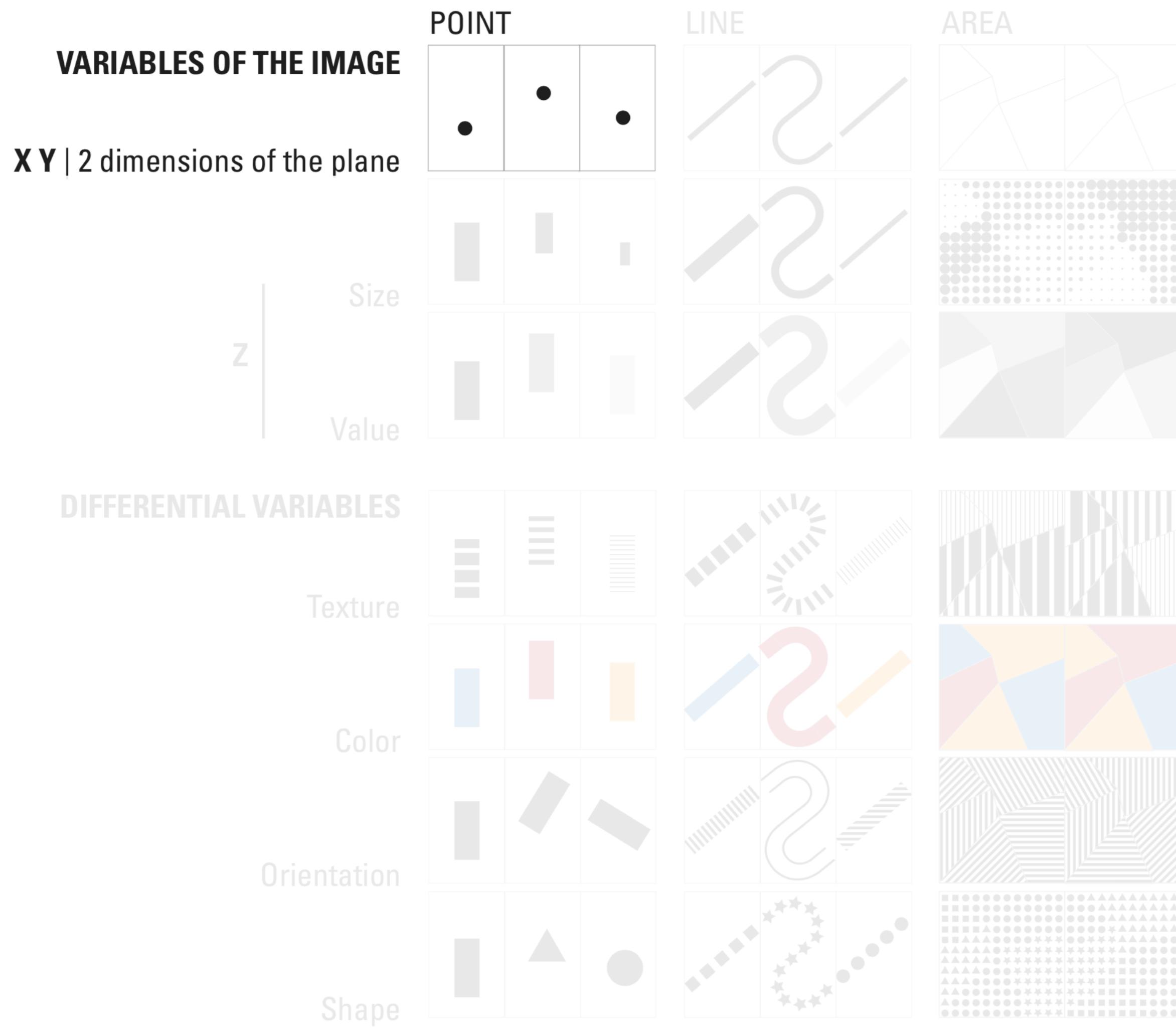
data encodings for visual comparison

data encodings, visual channels for encoding data



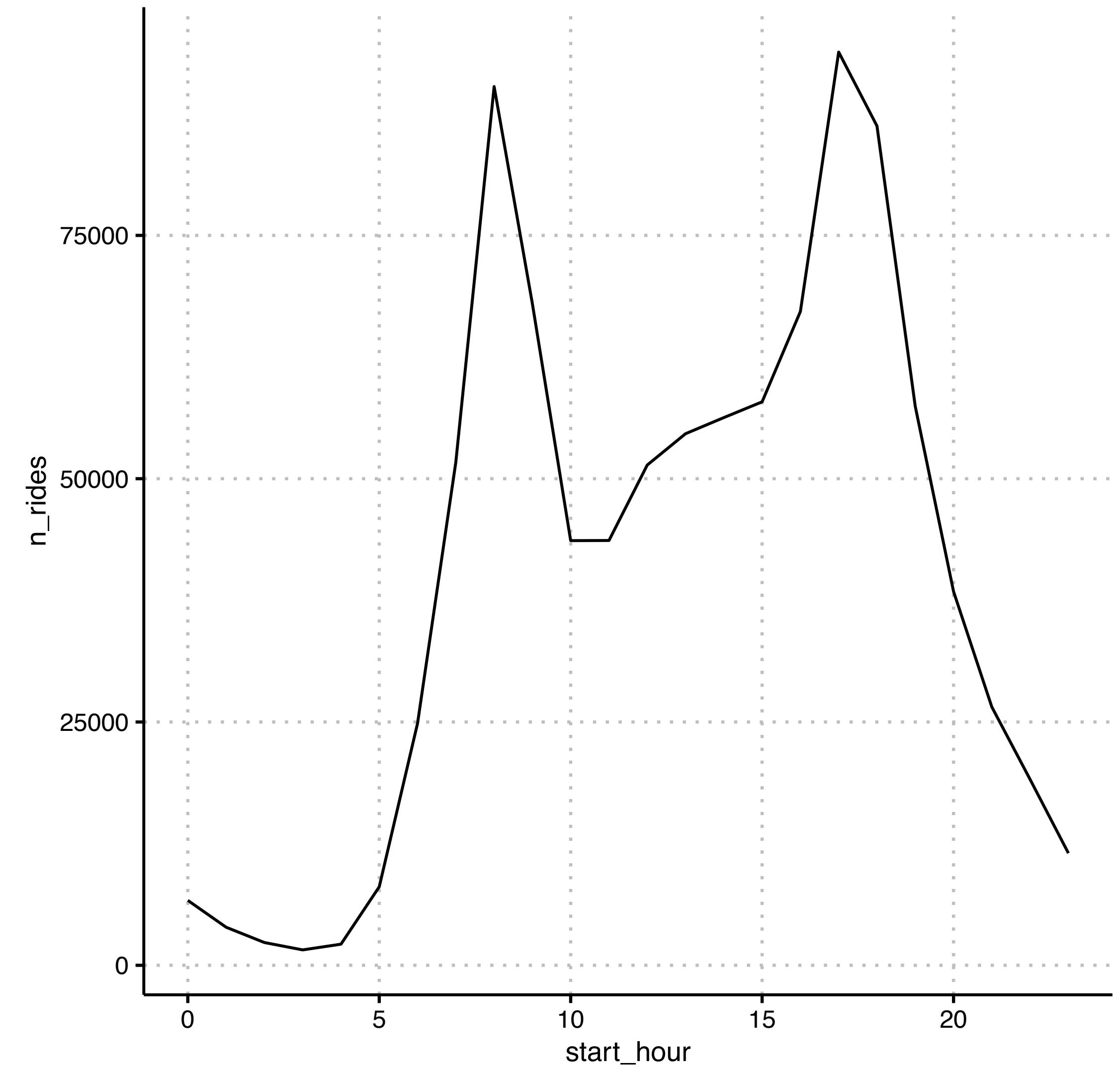
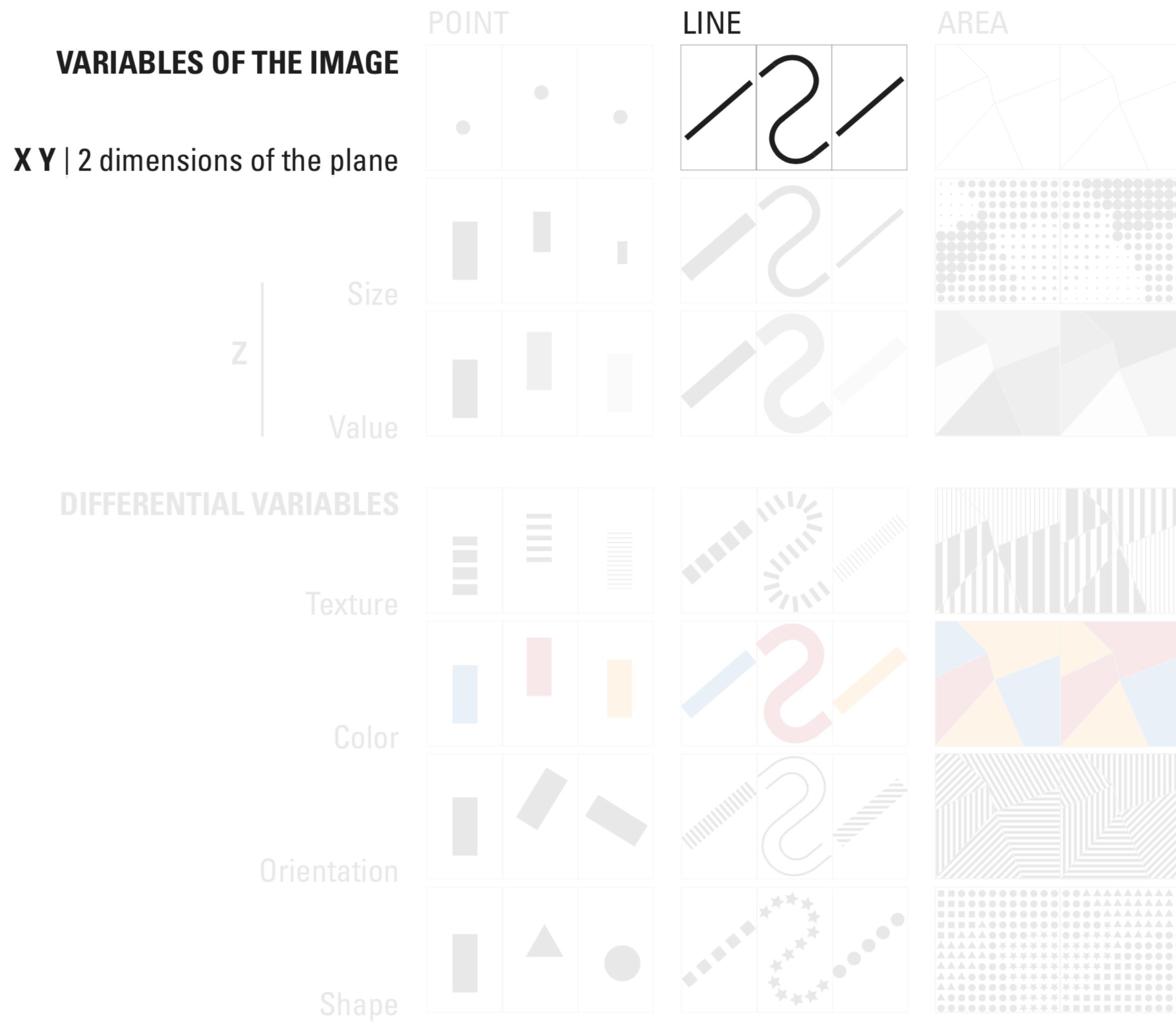
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



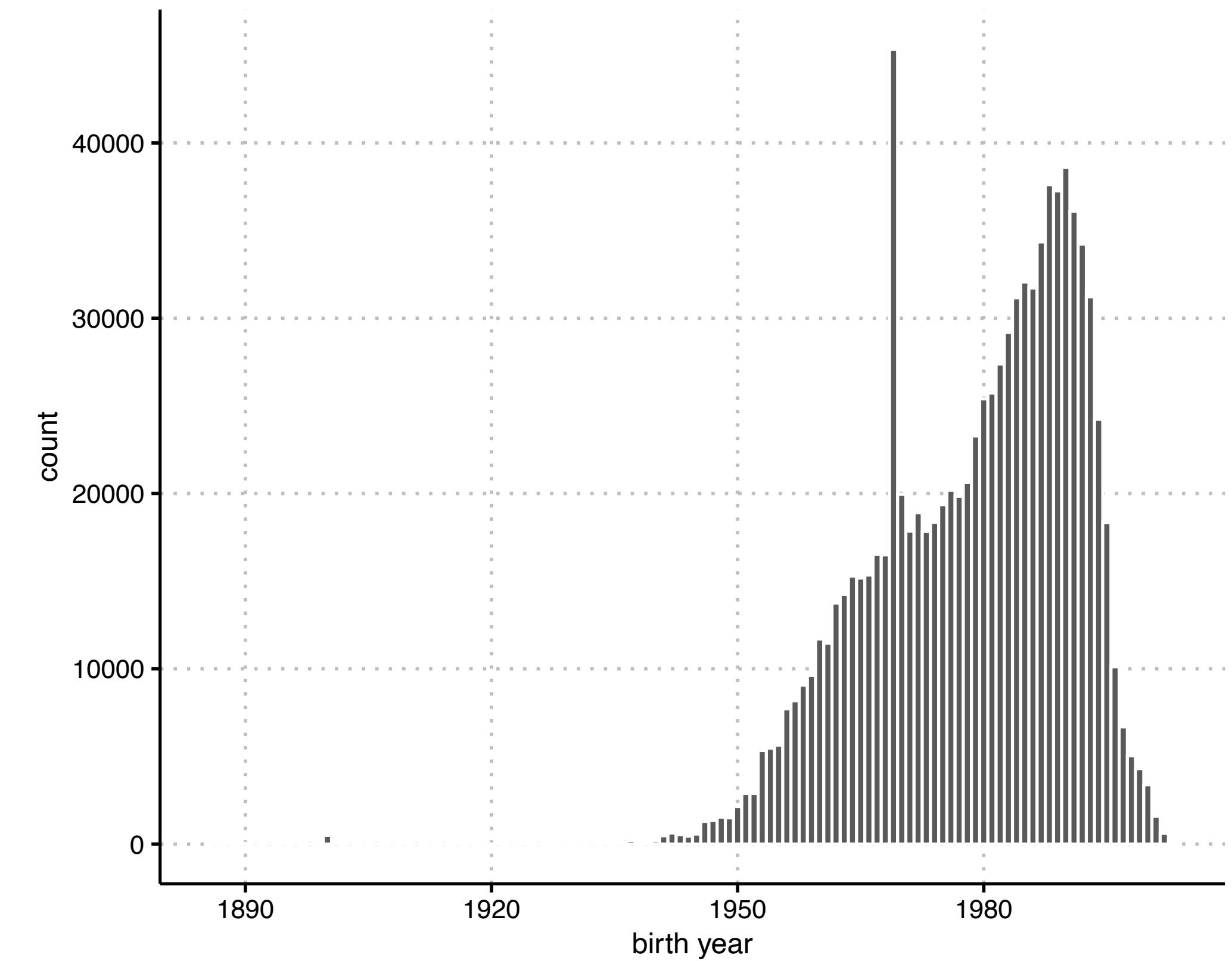
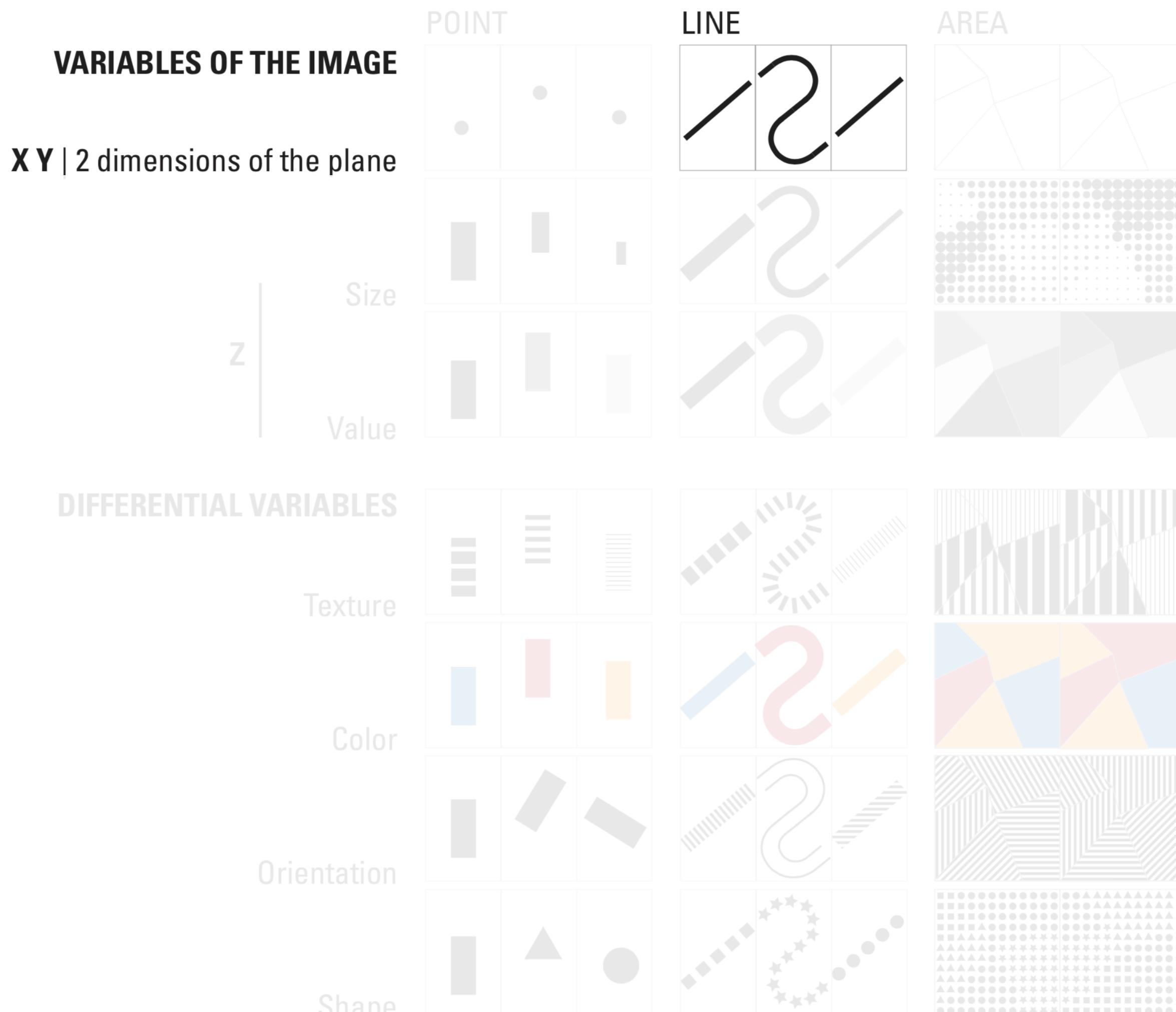
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



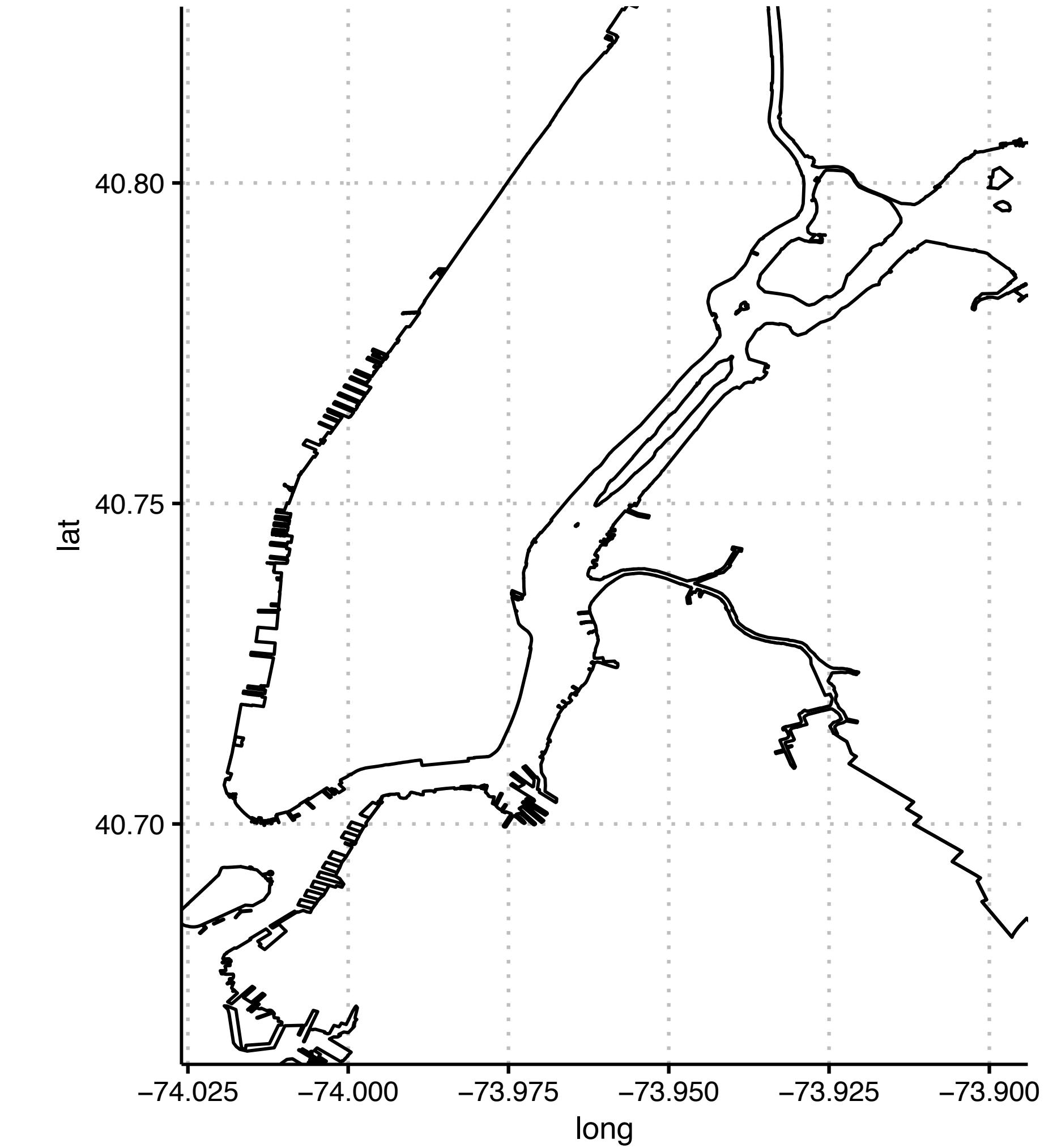
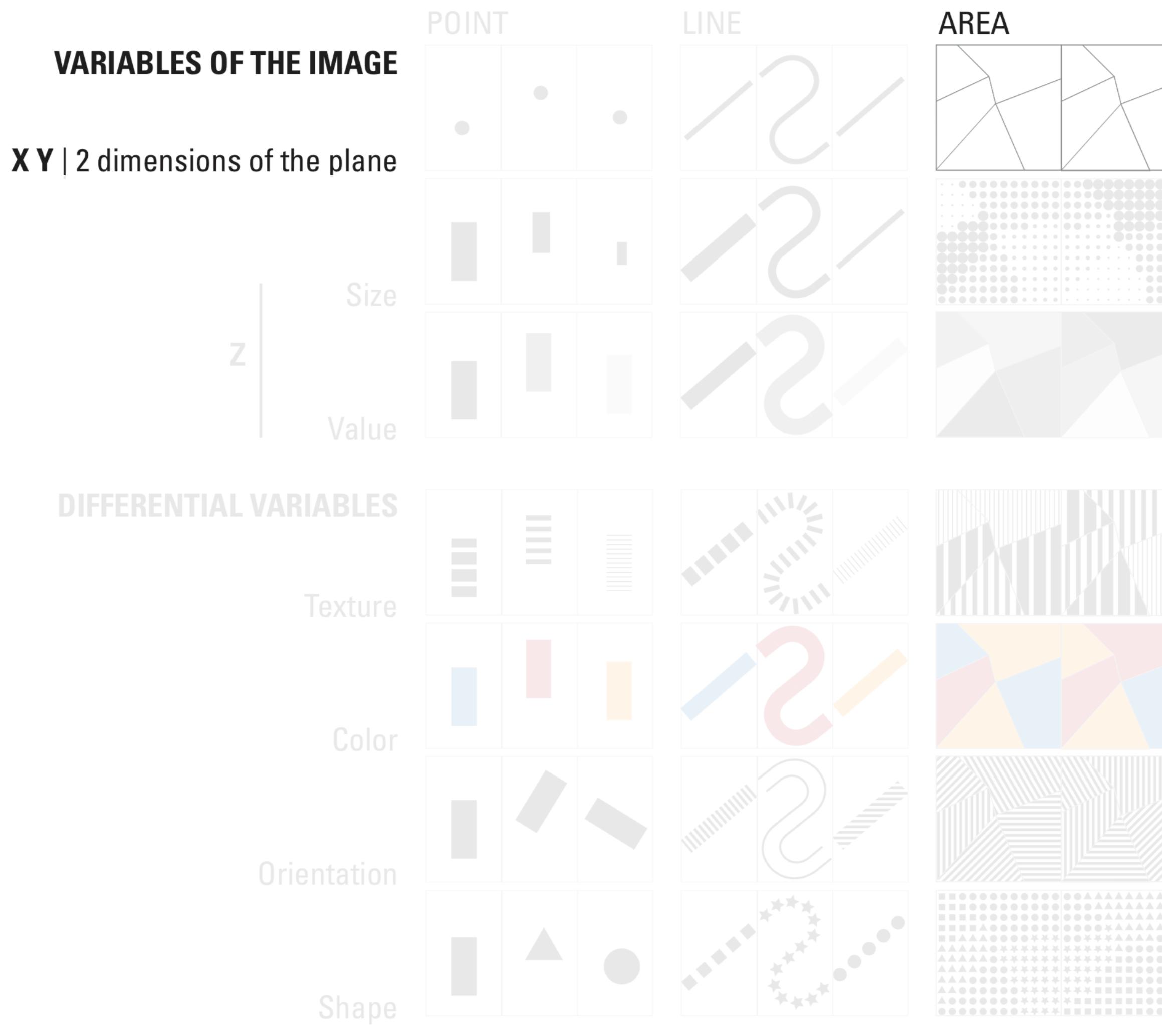
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



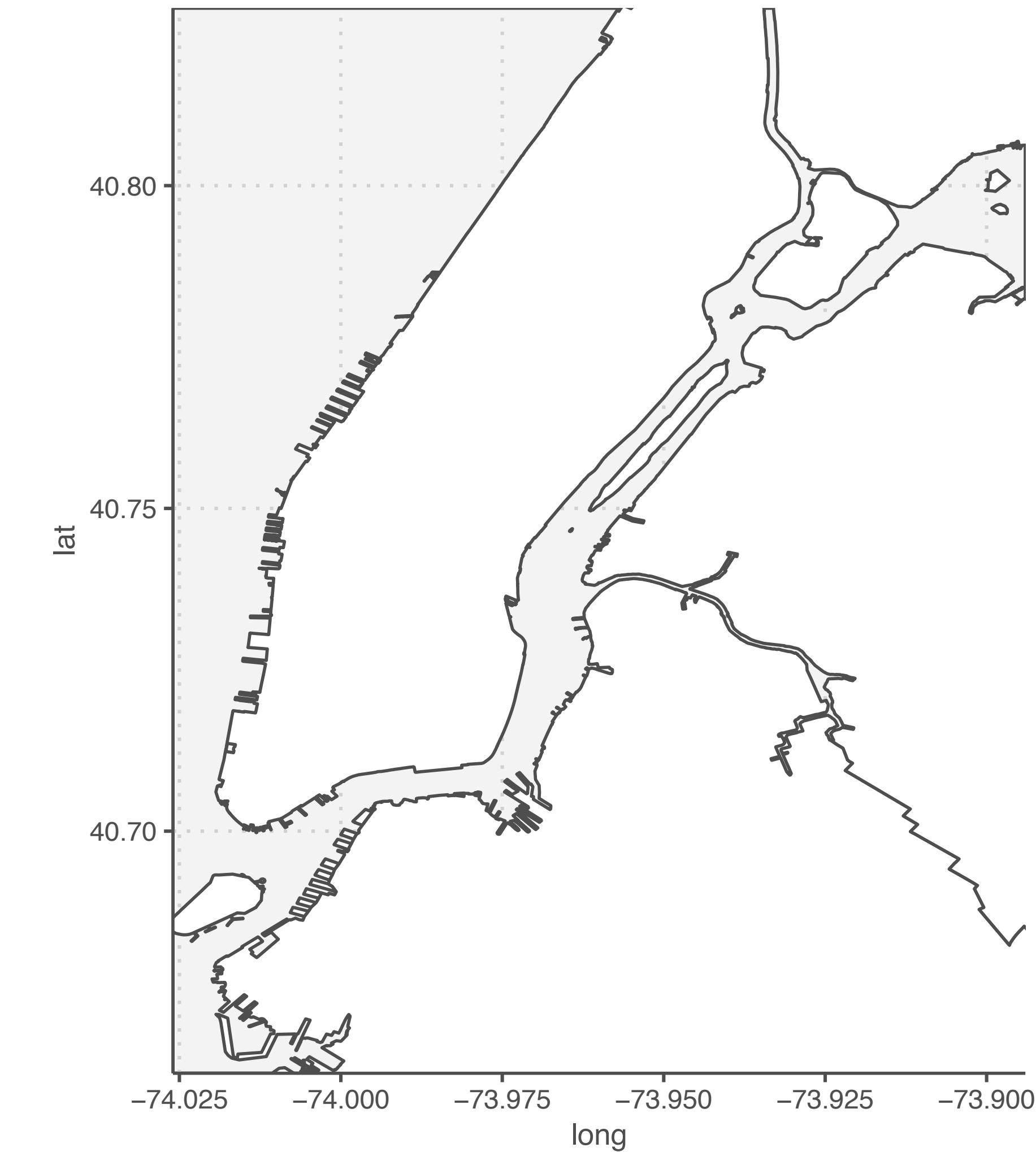
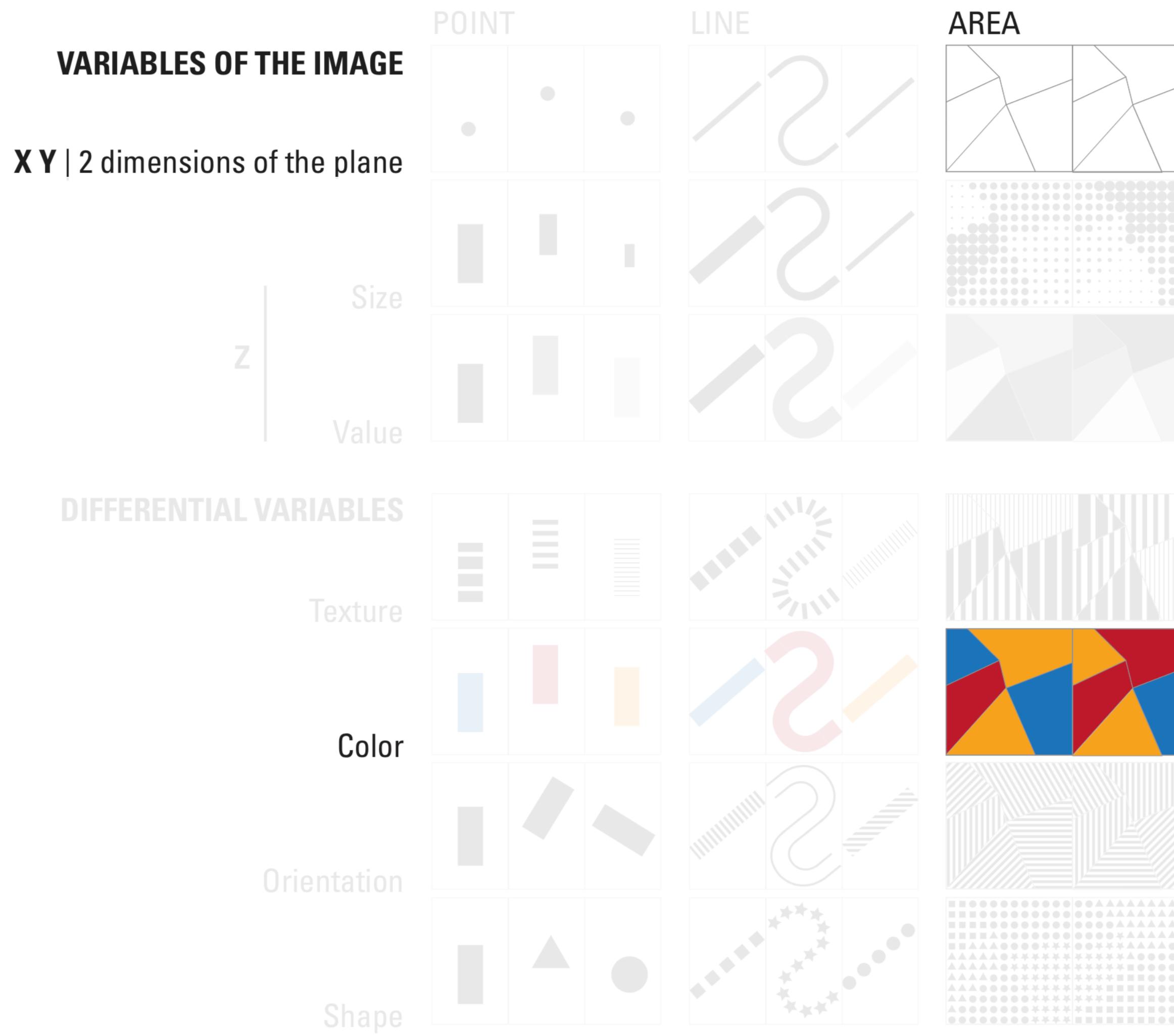
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



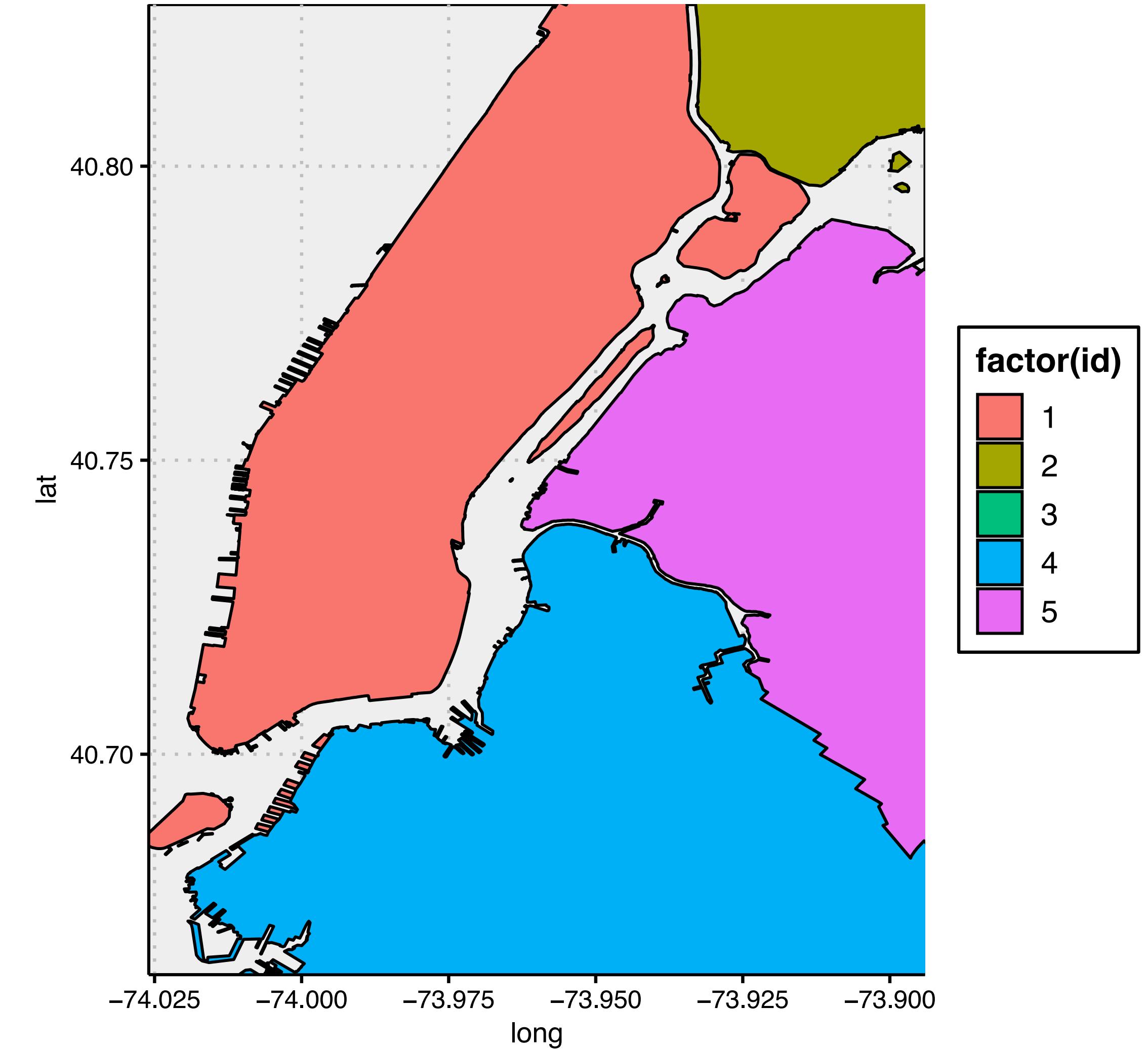
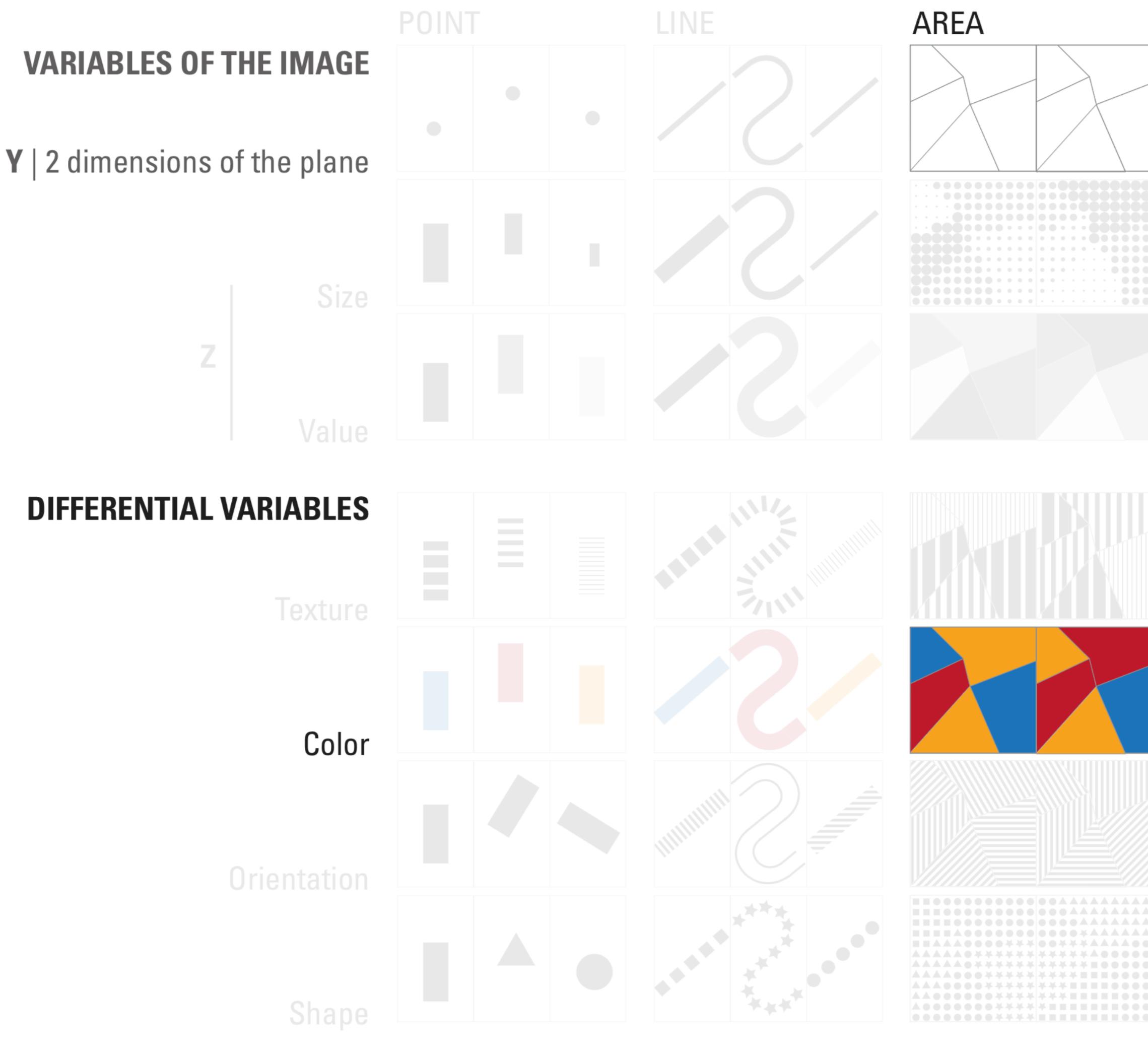
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



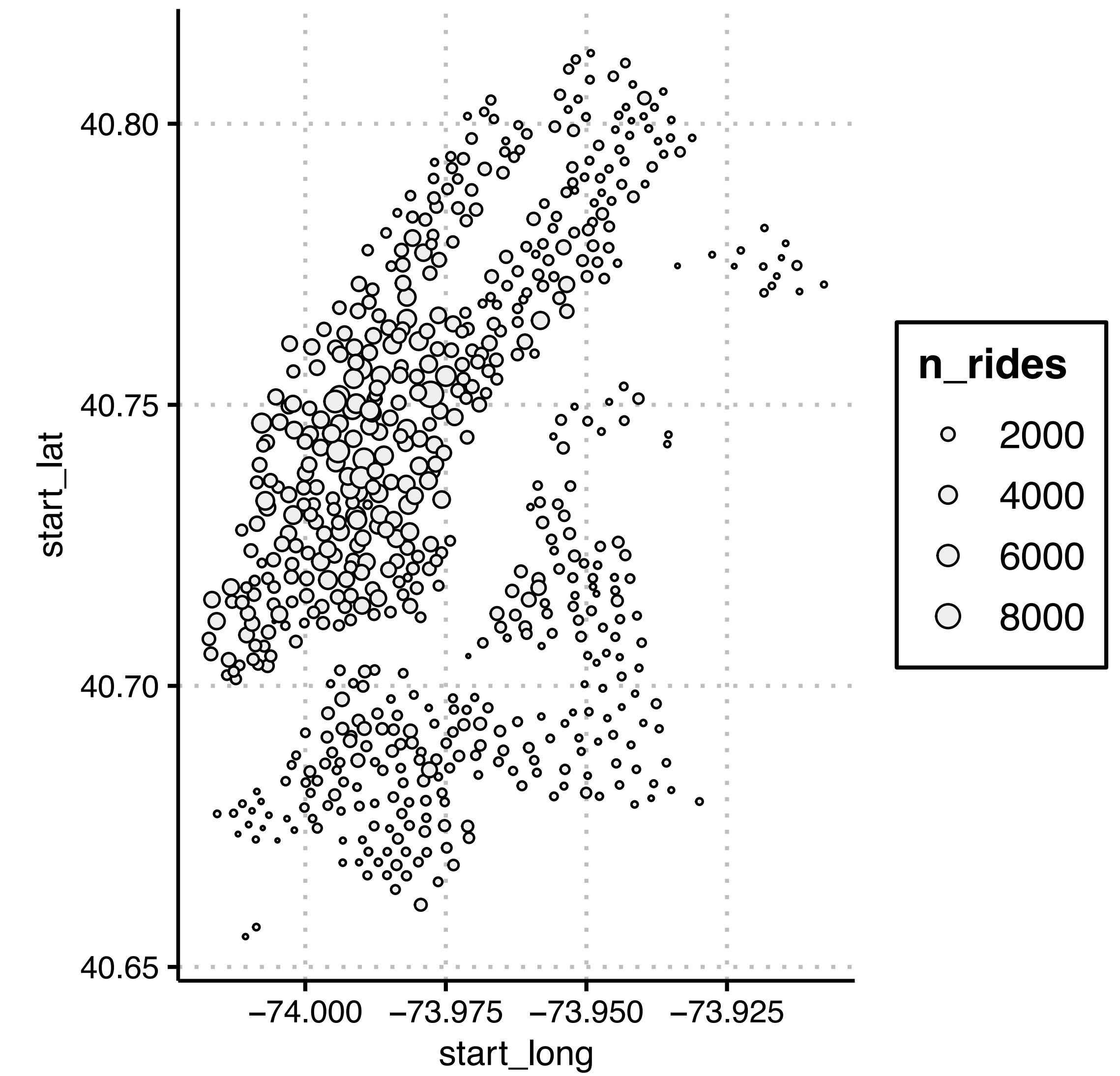
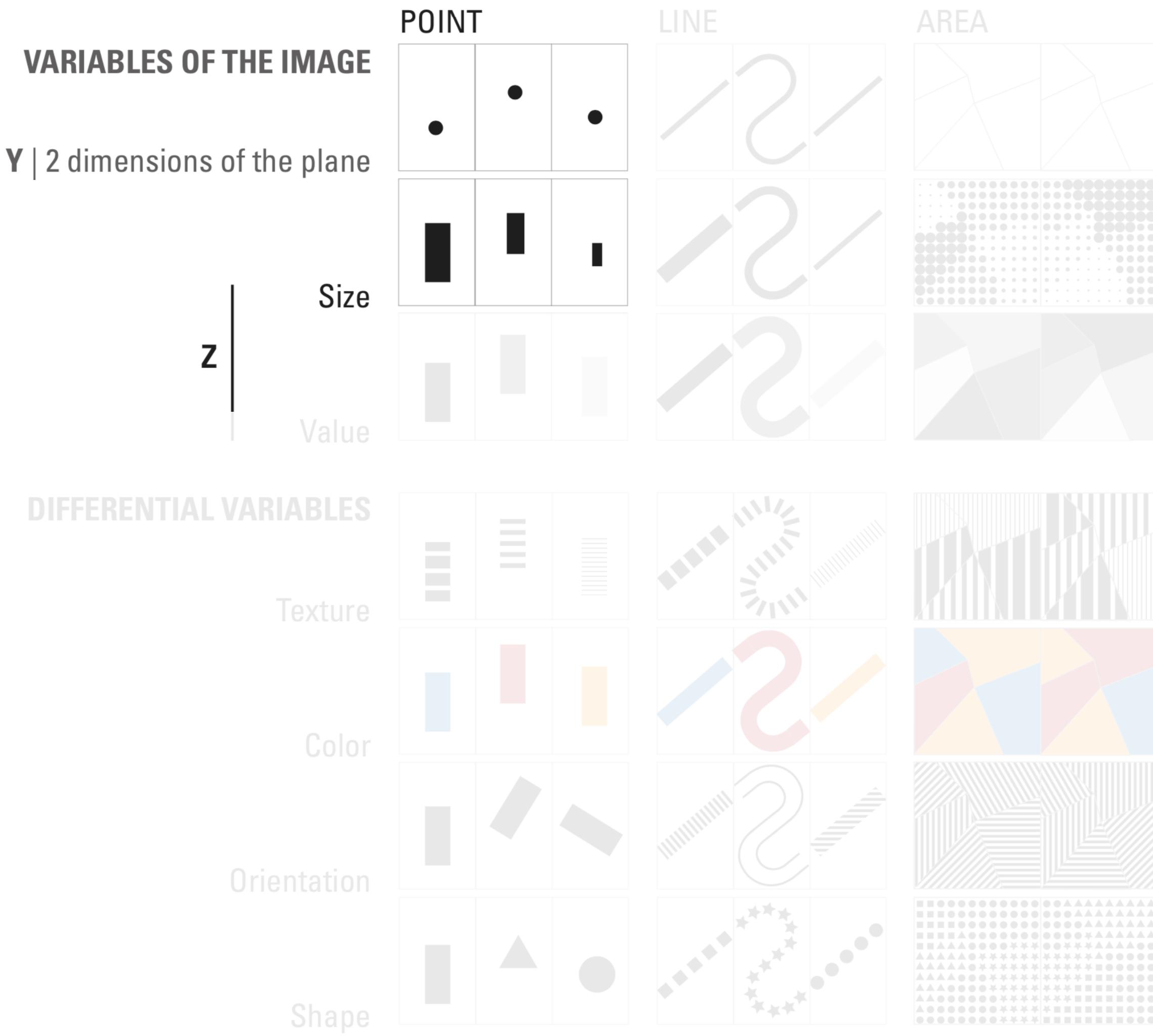
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



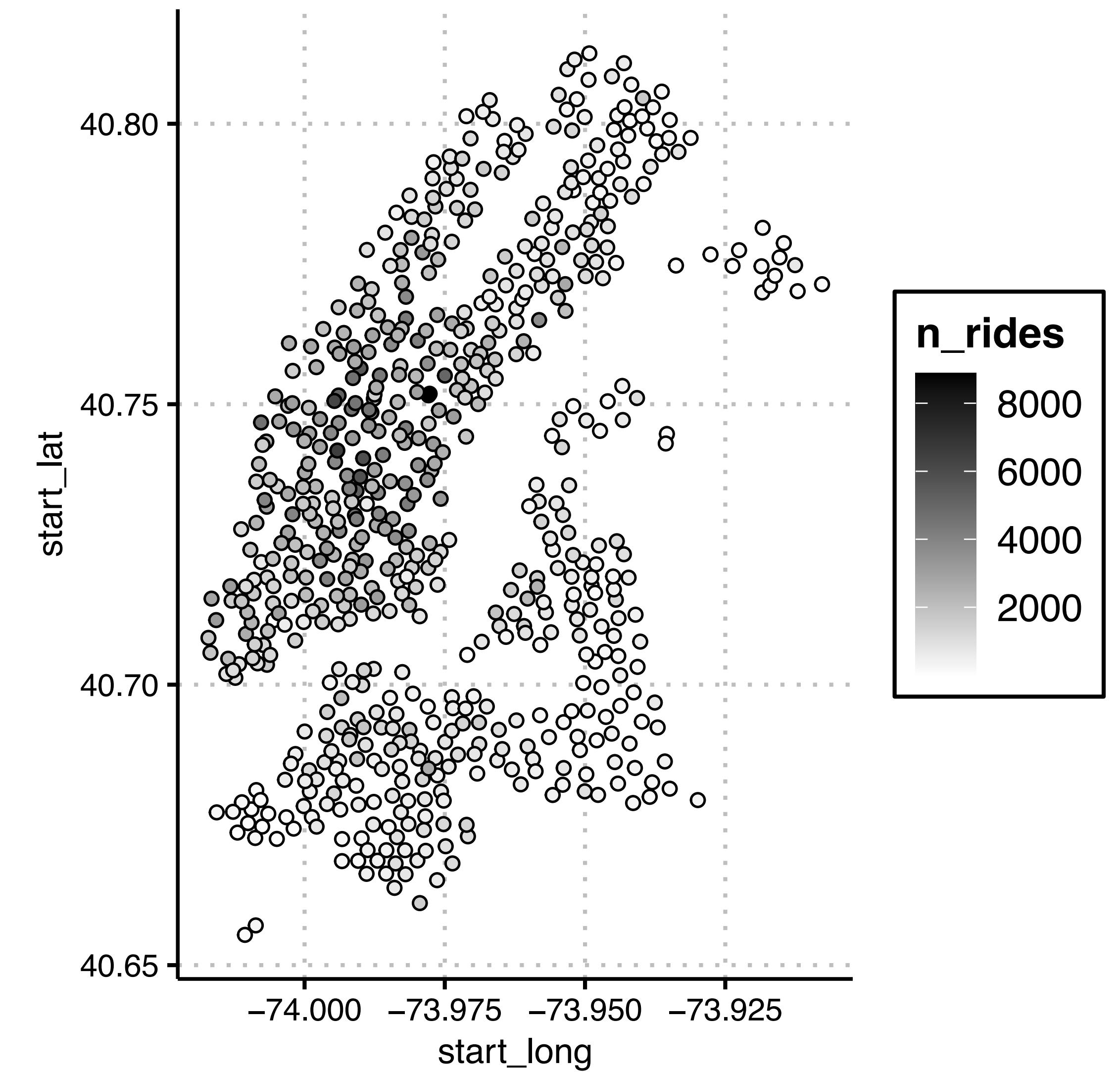
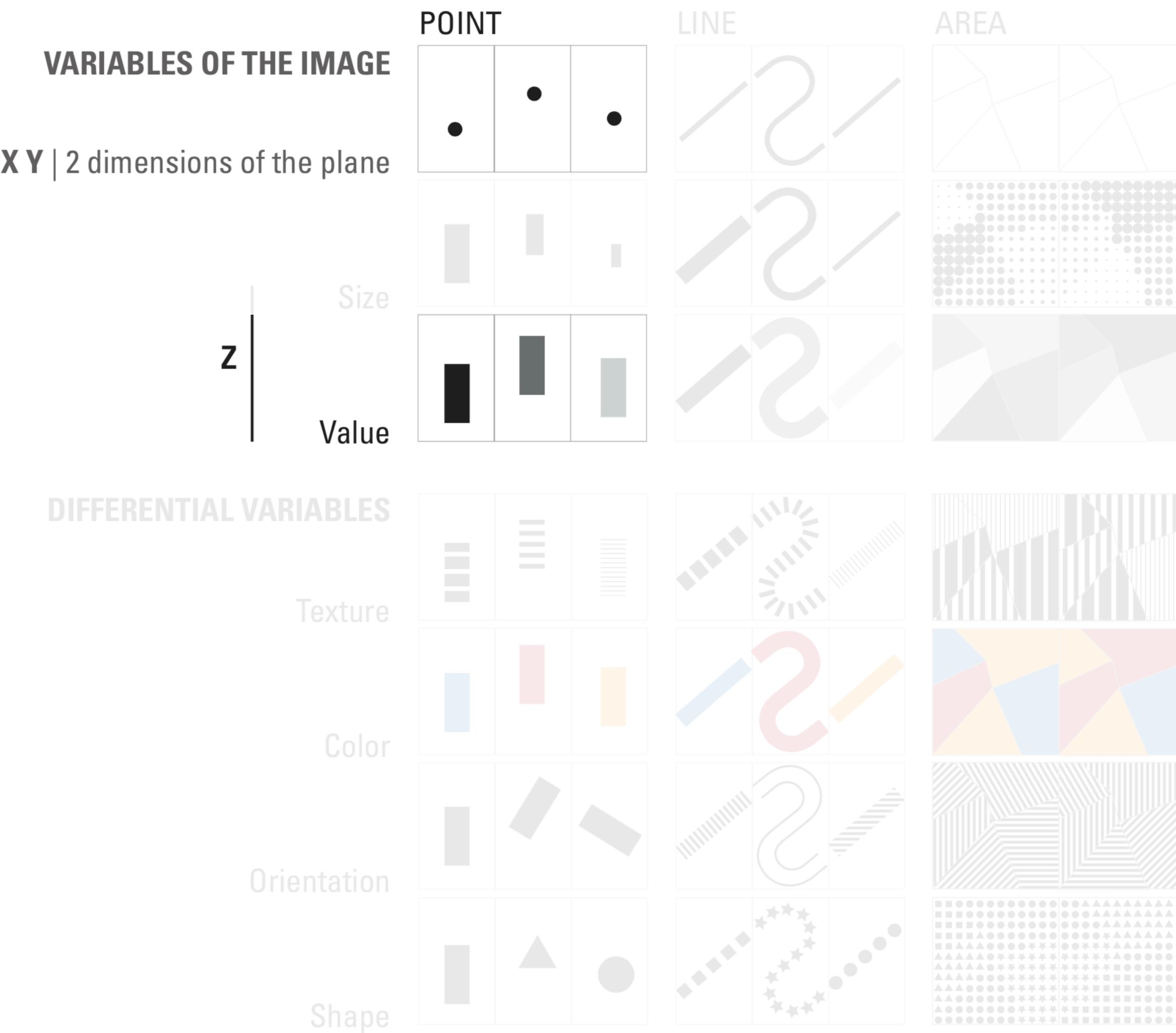
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



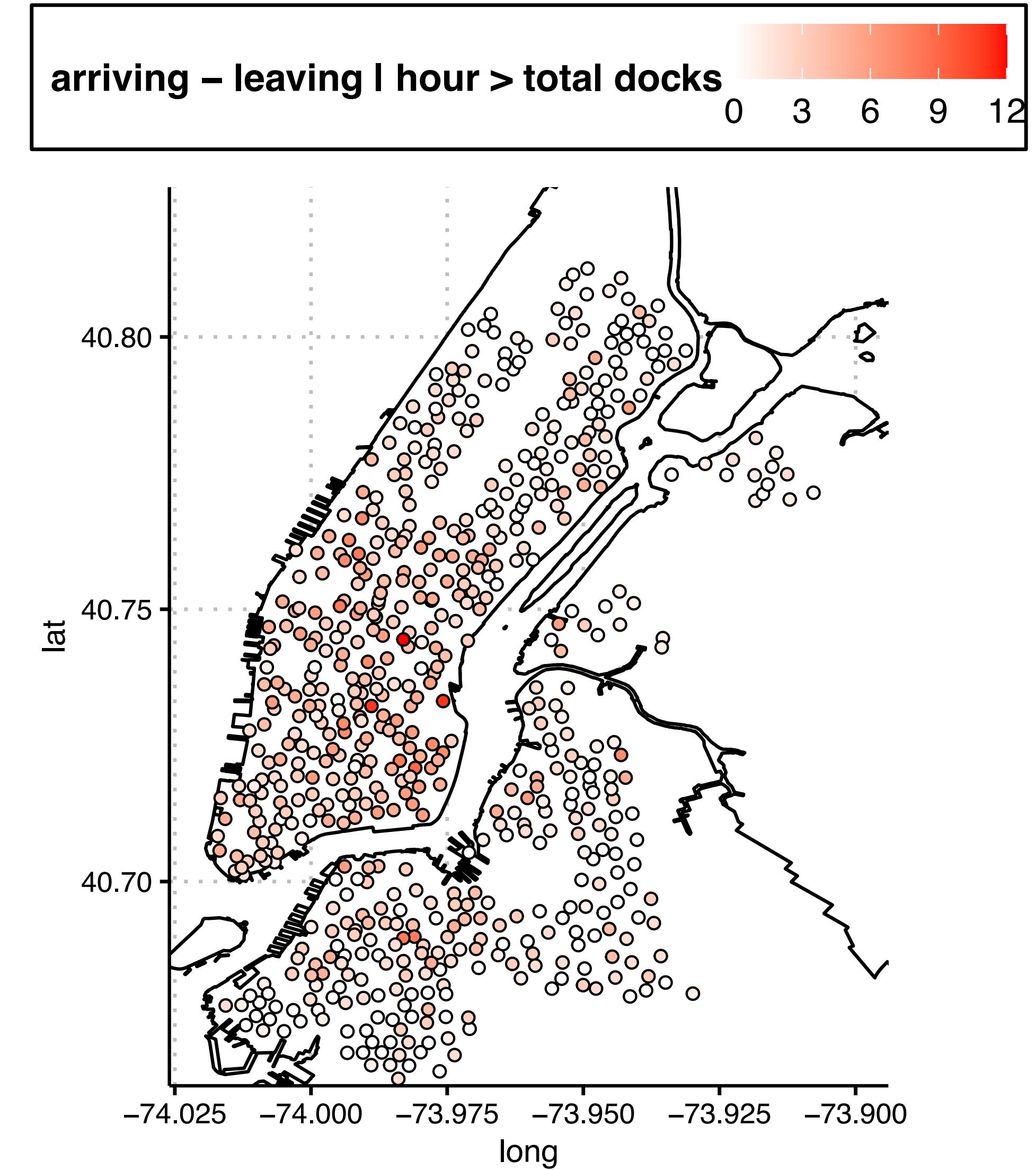
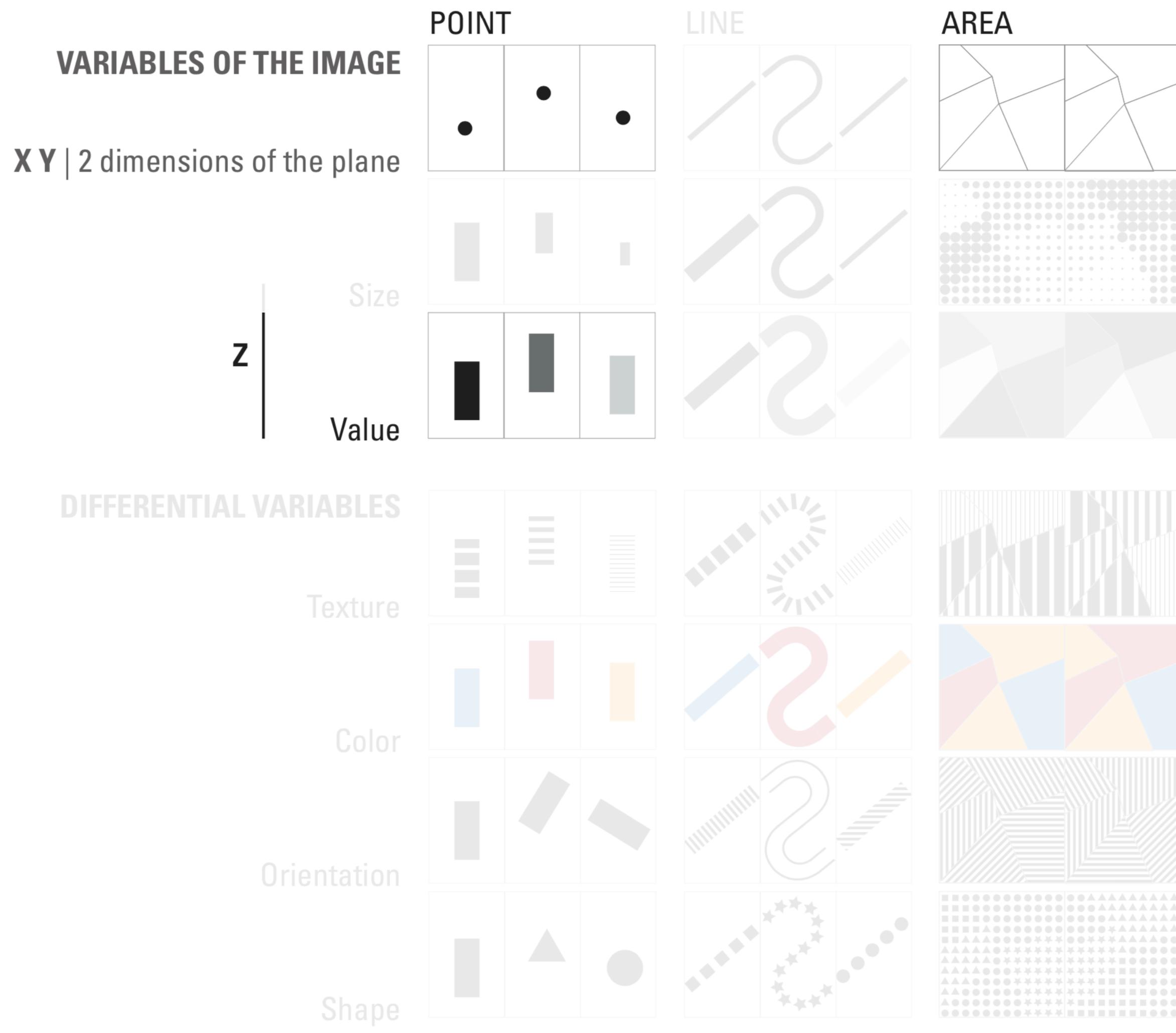
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



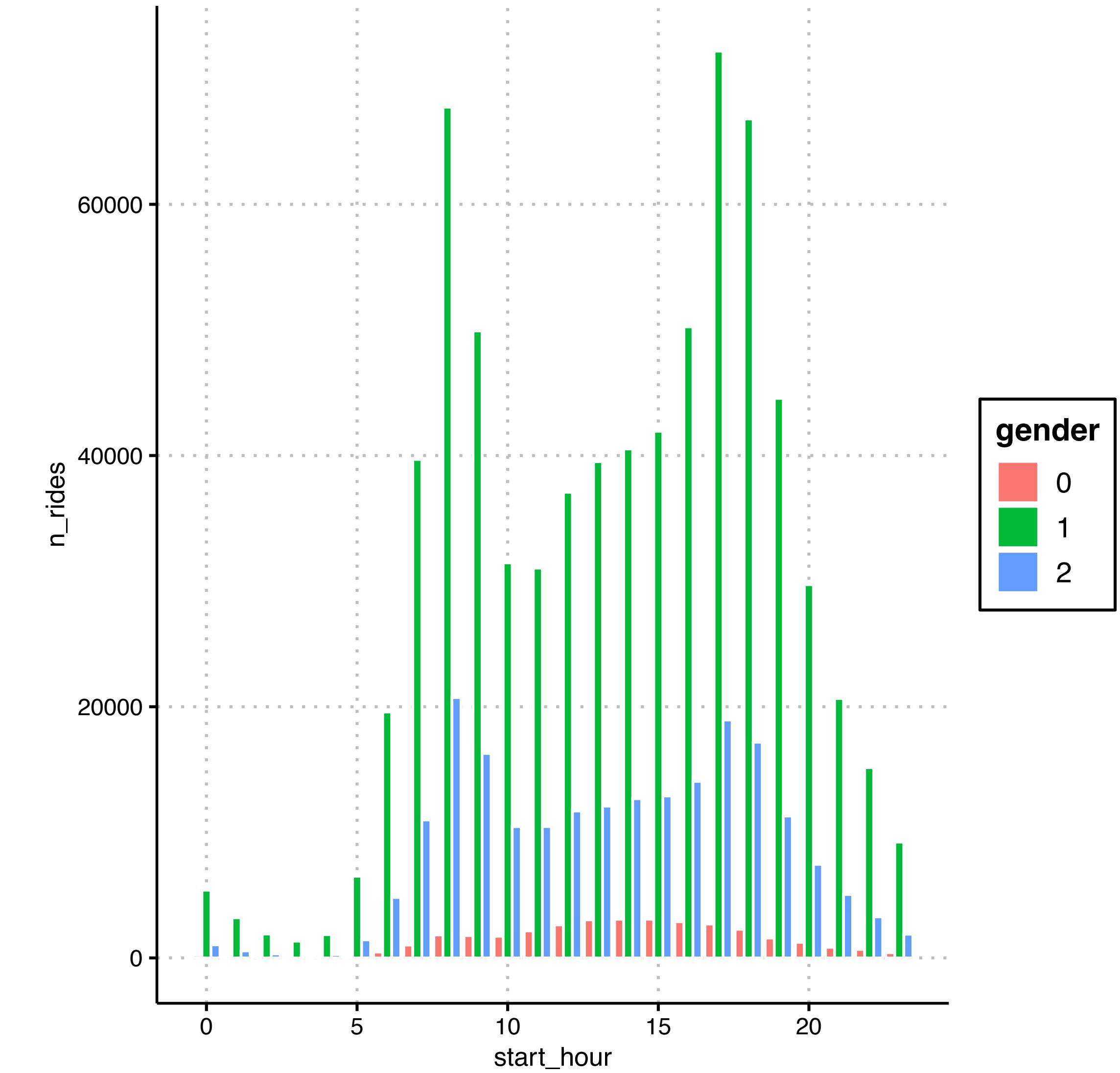
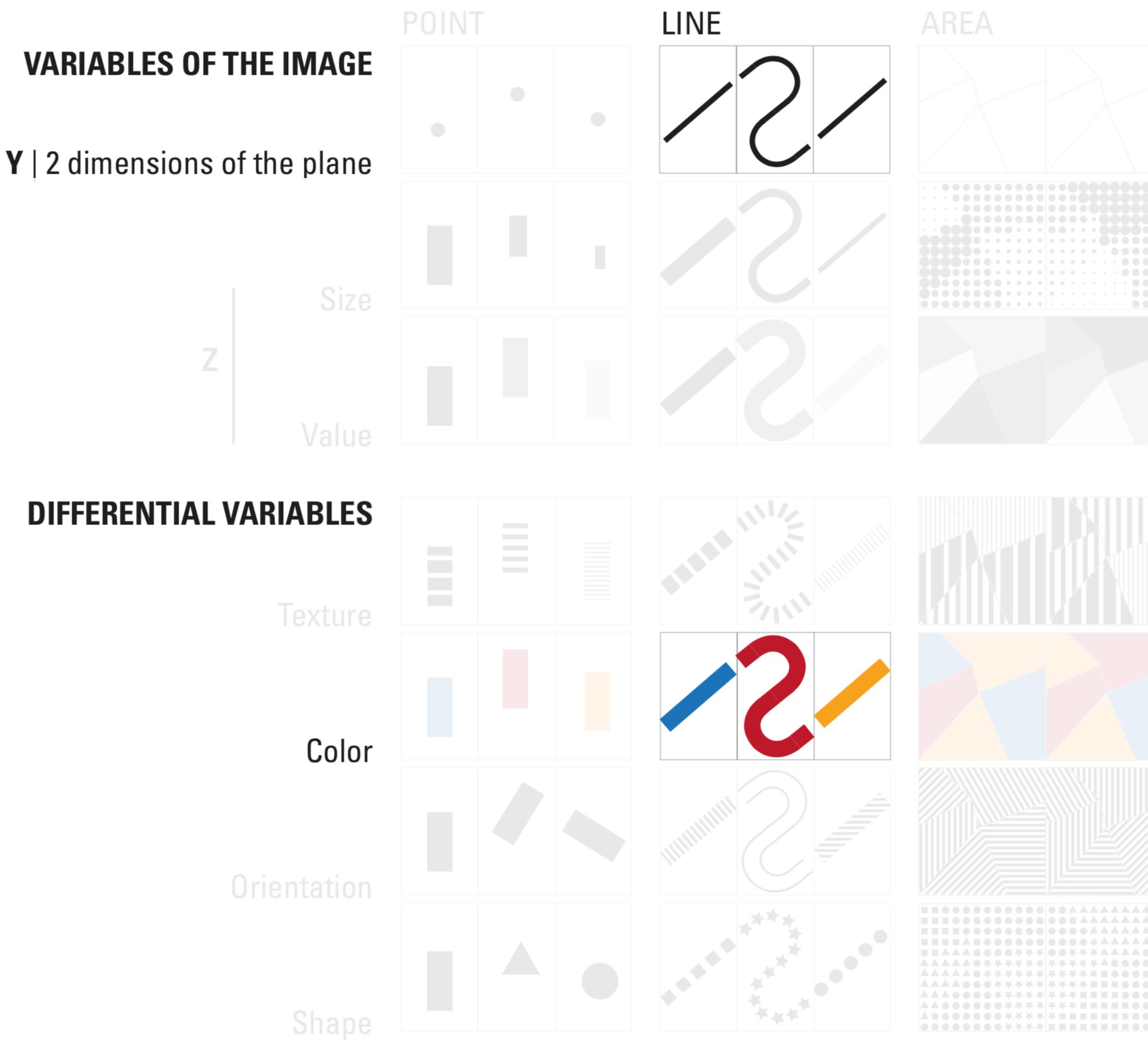
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



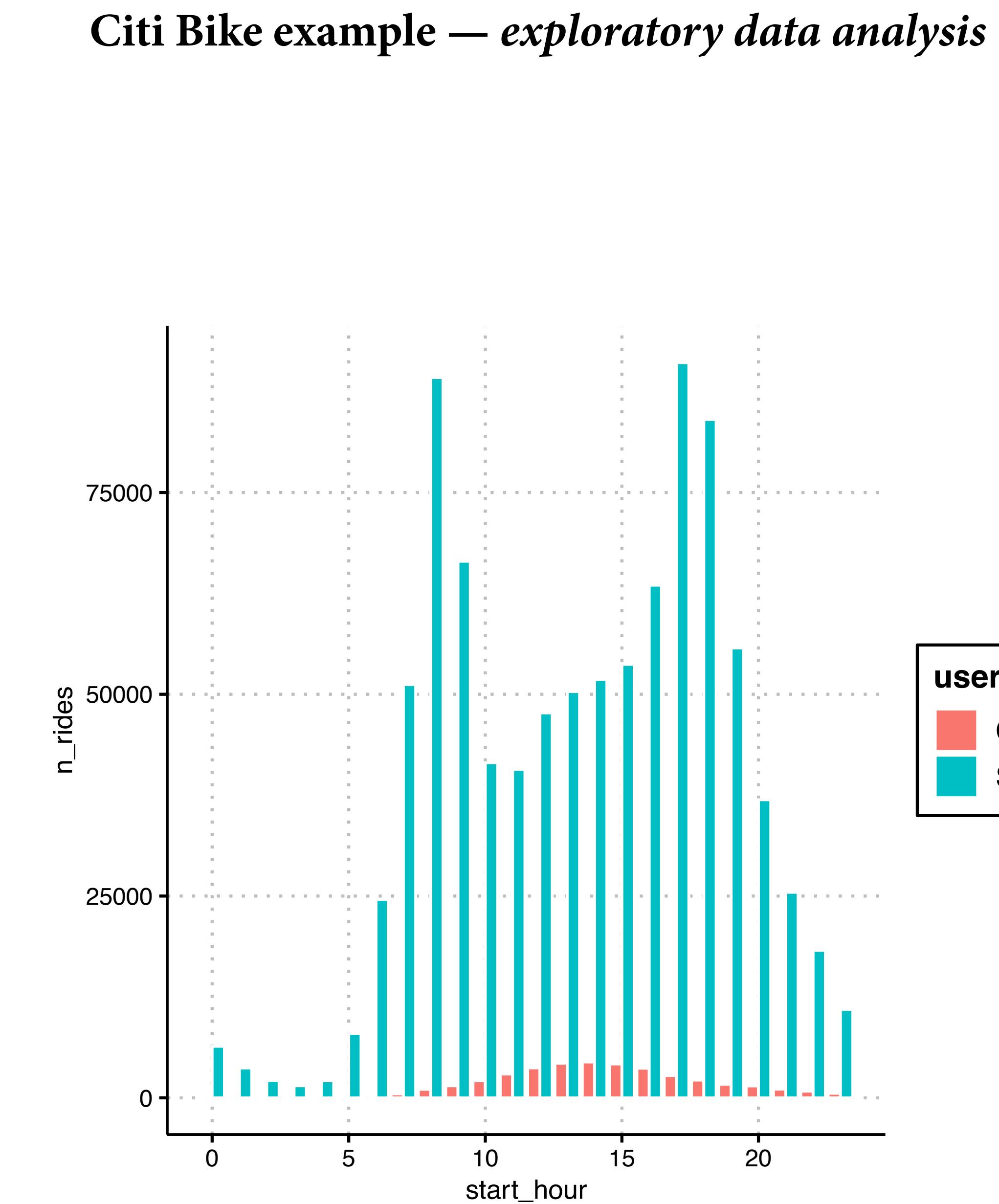
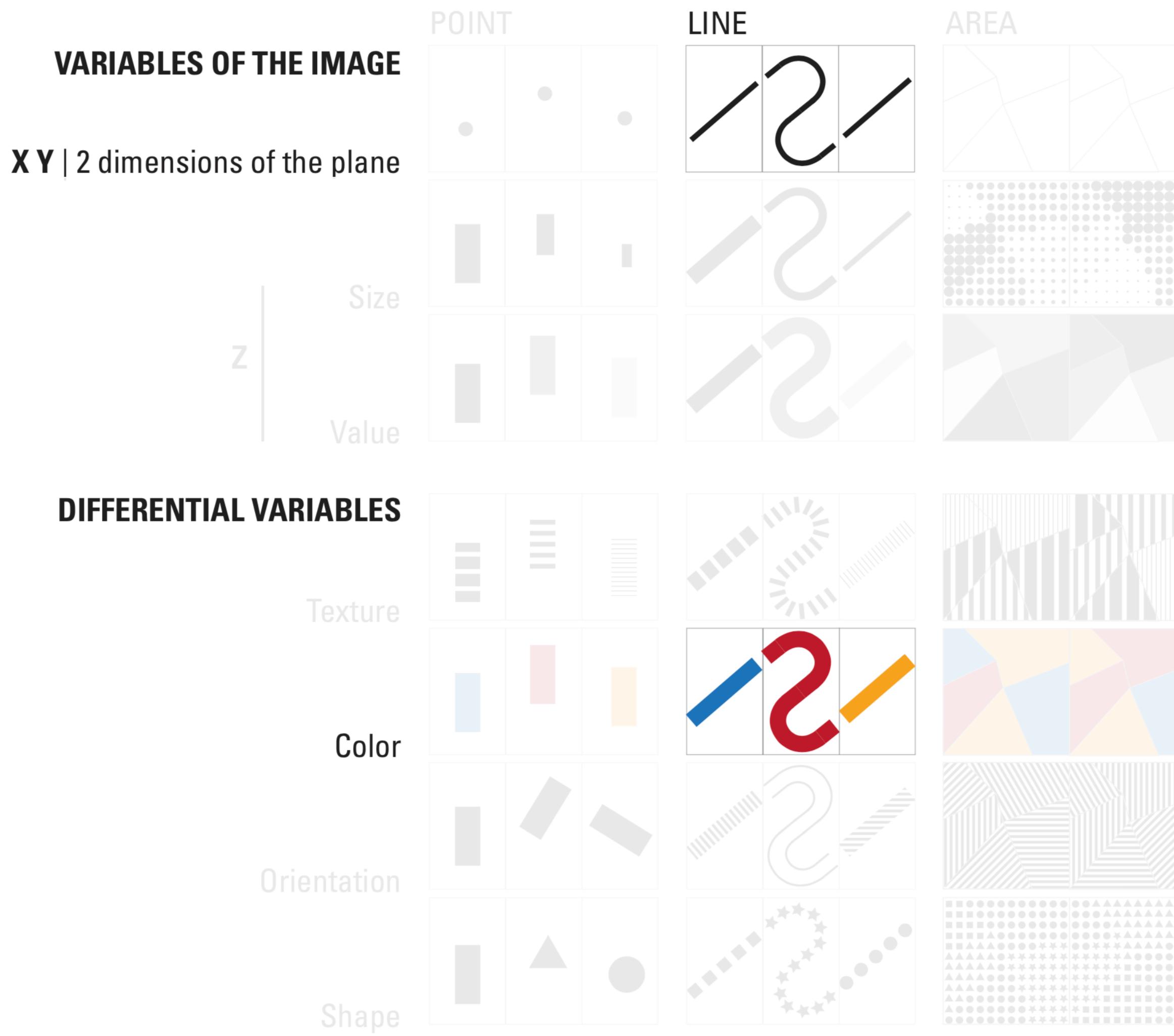
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



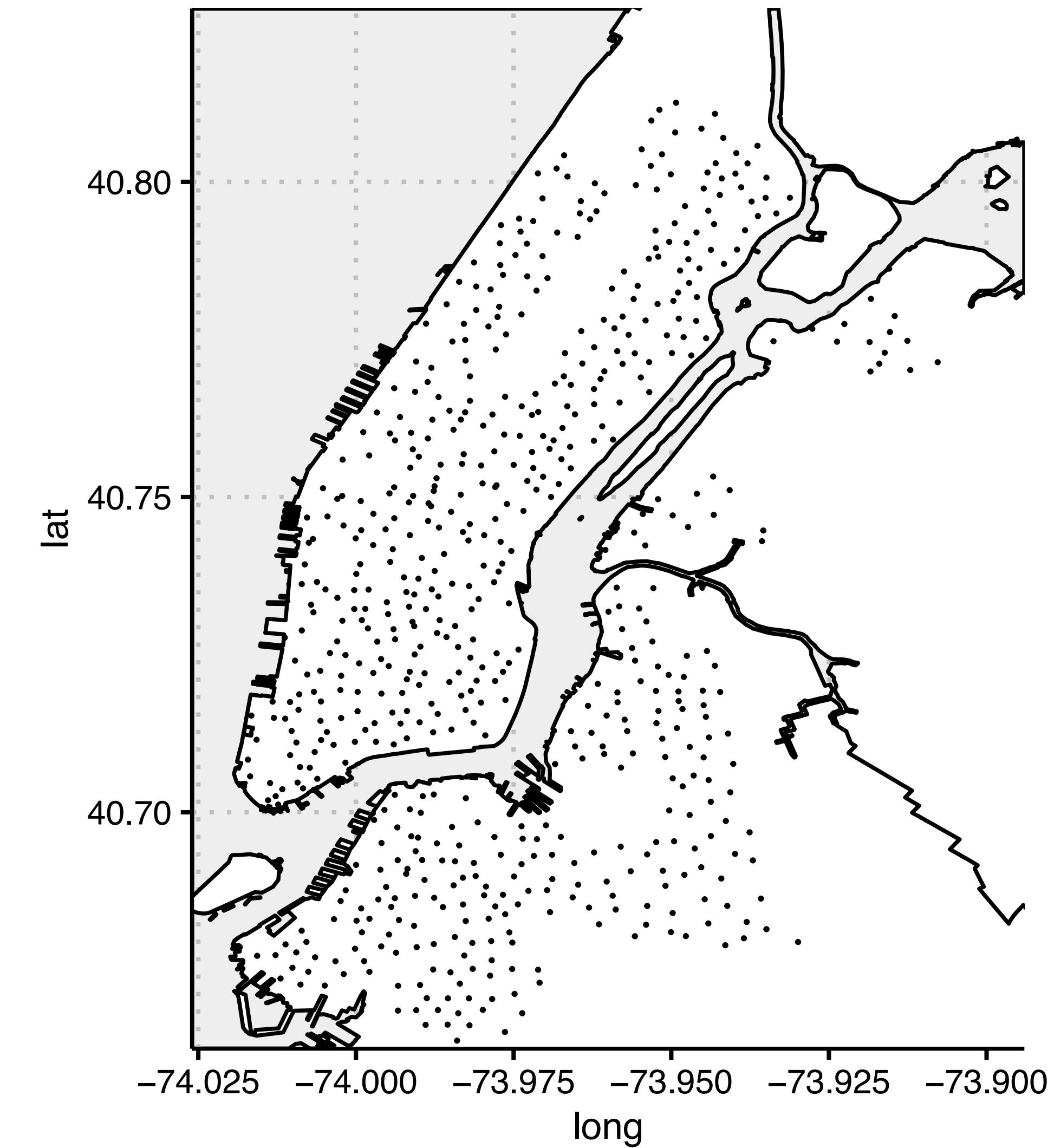
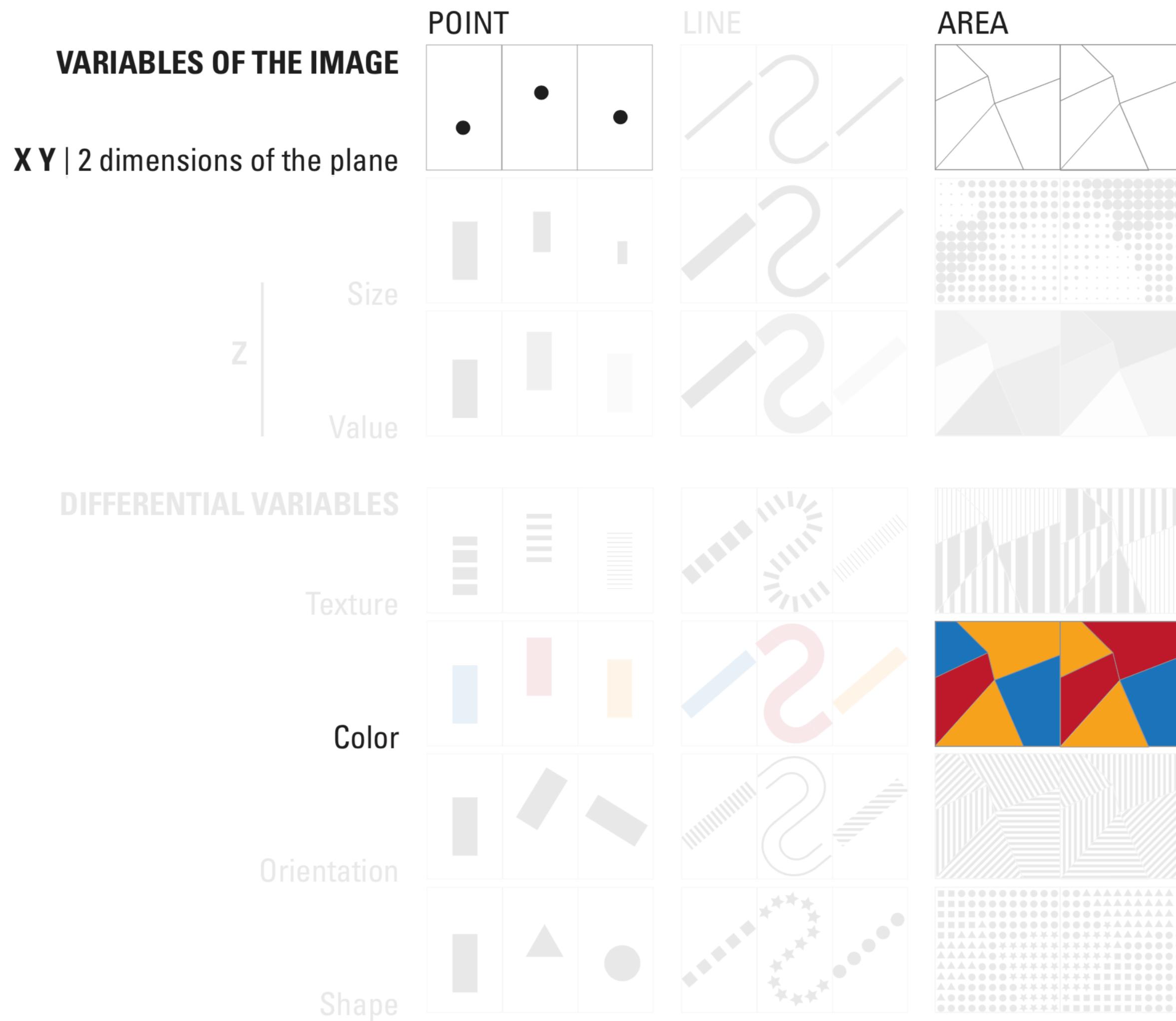
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



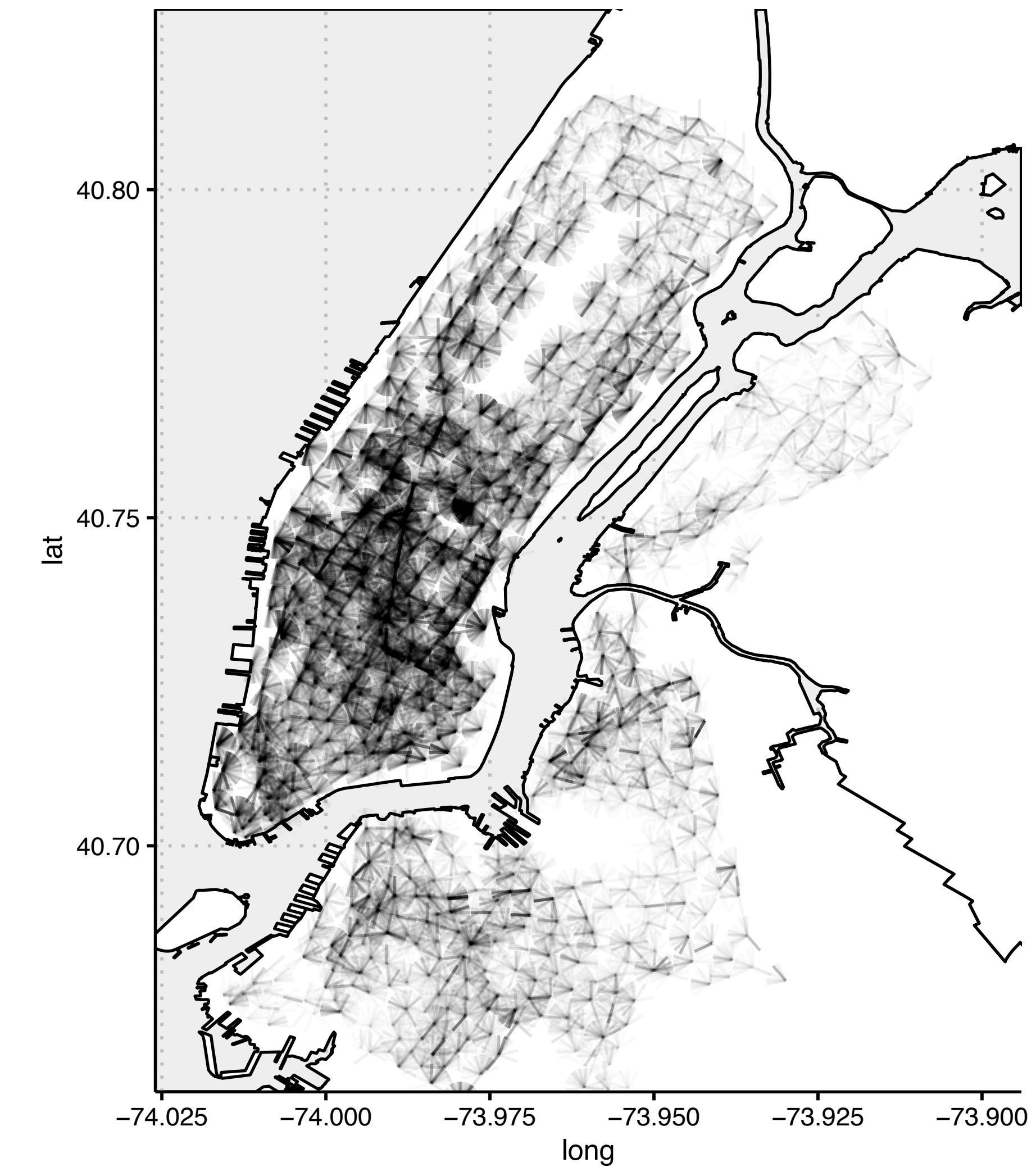
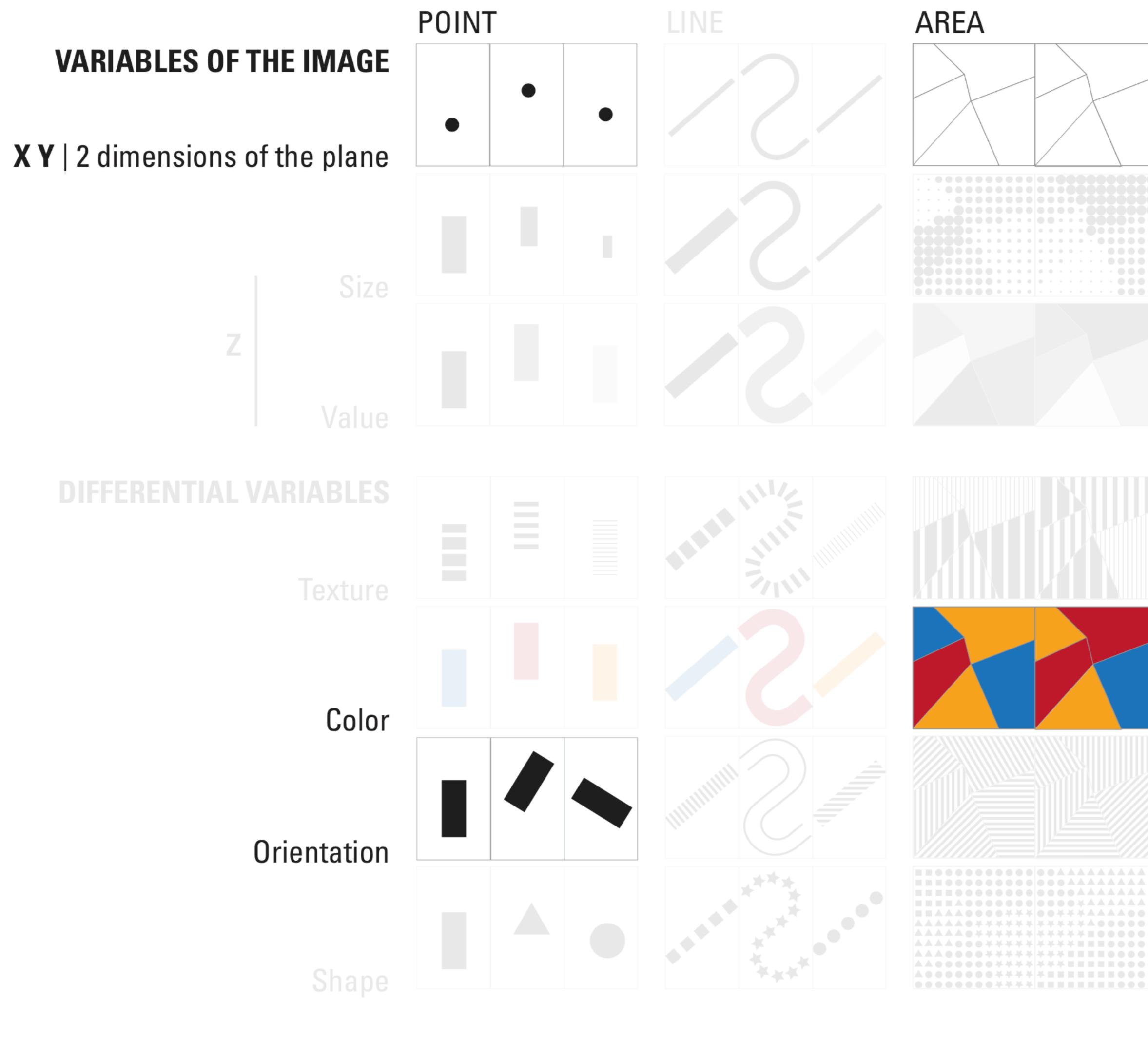
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



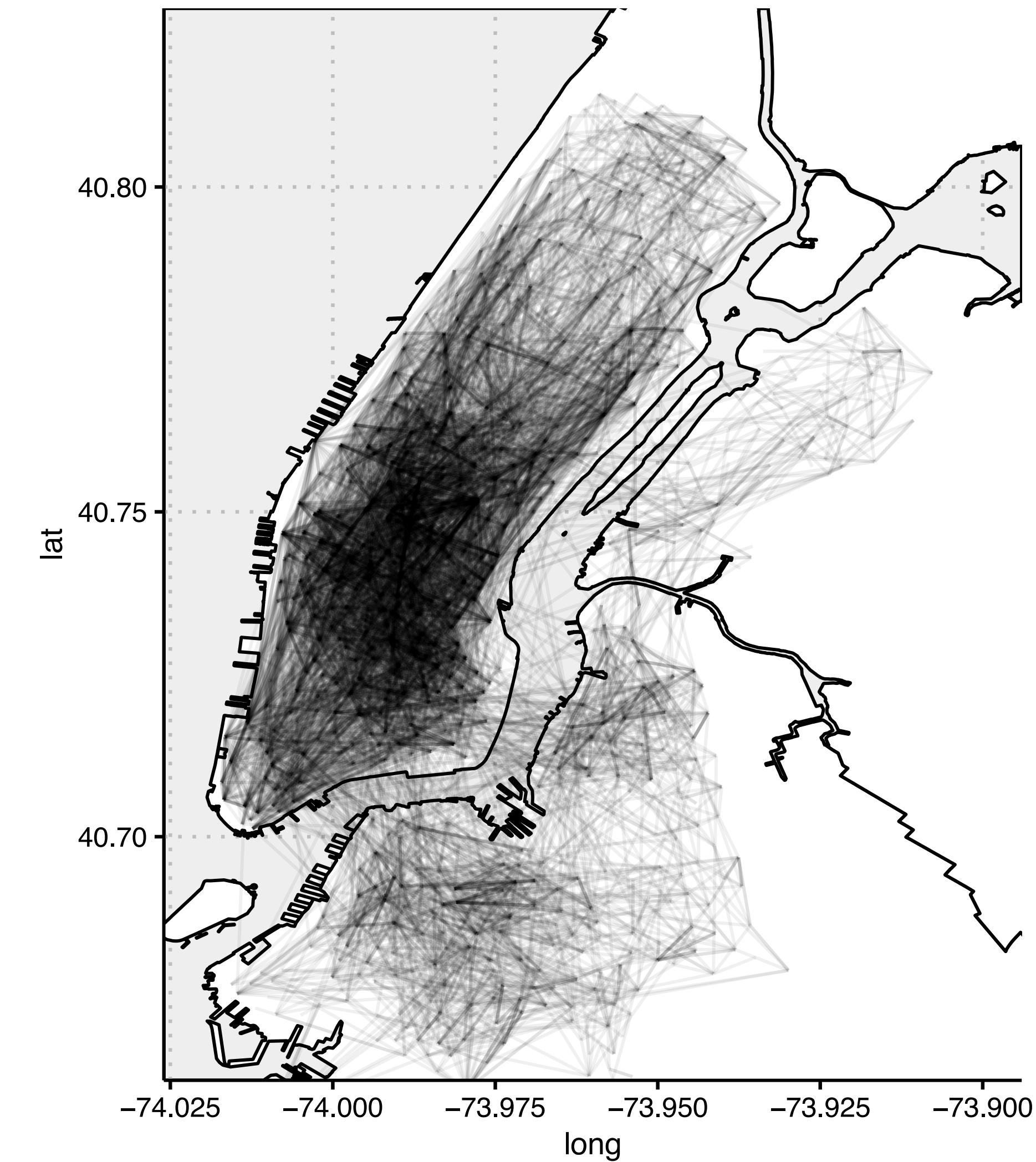
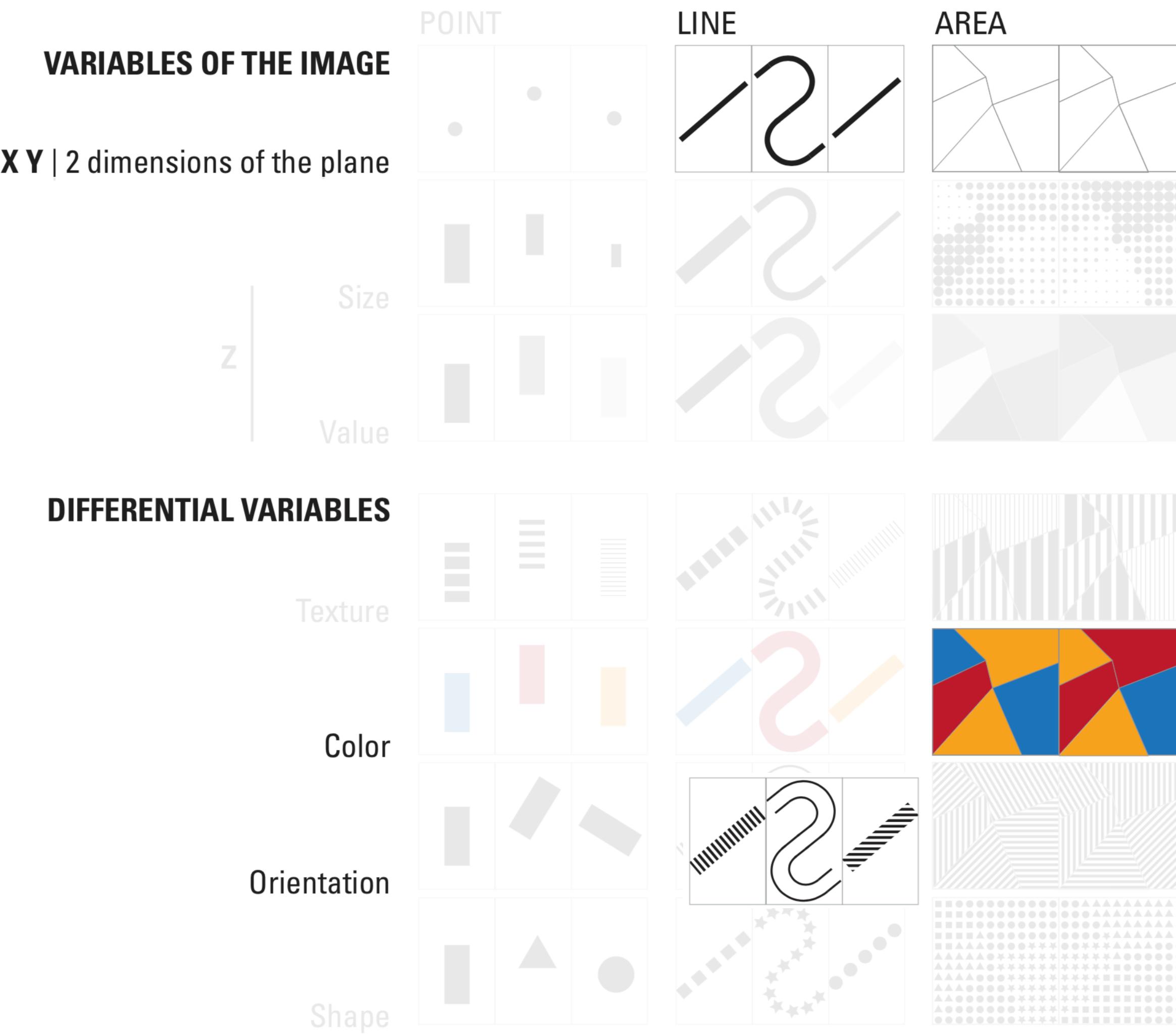
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



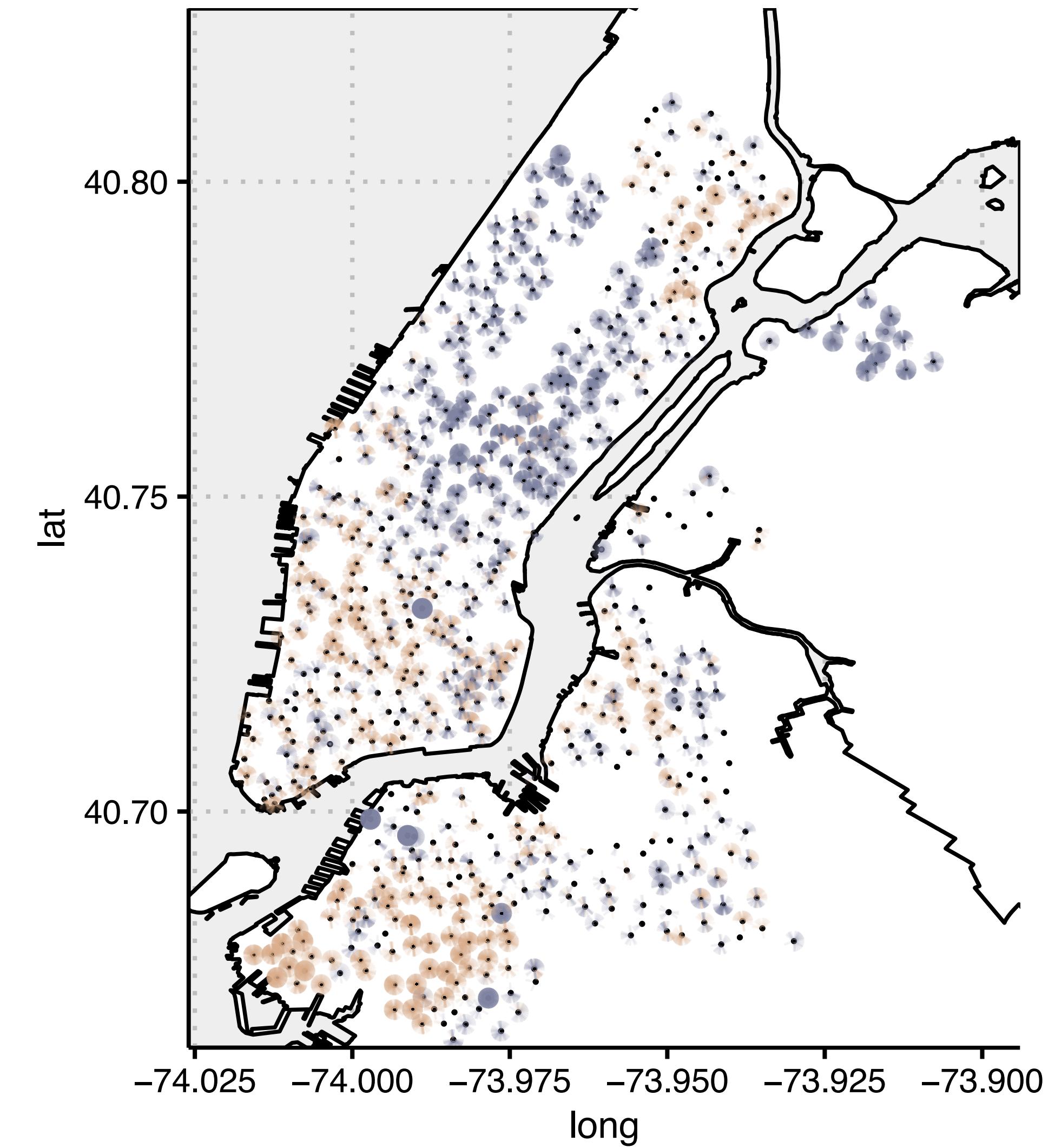
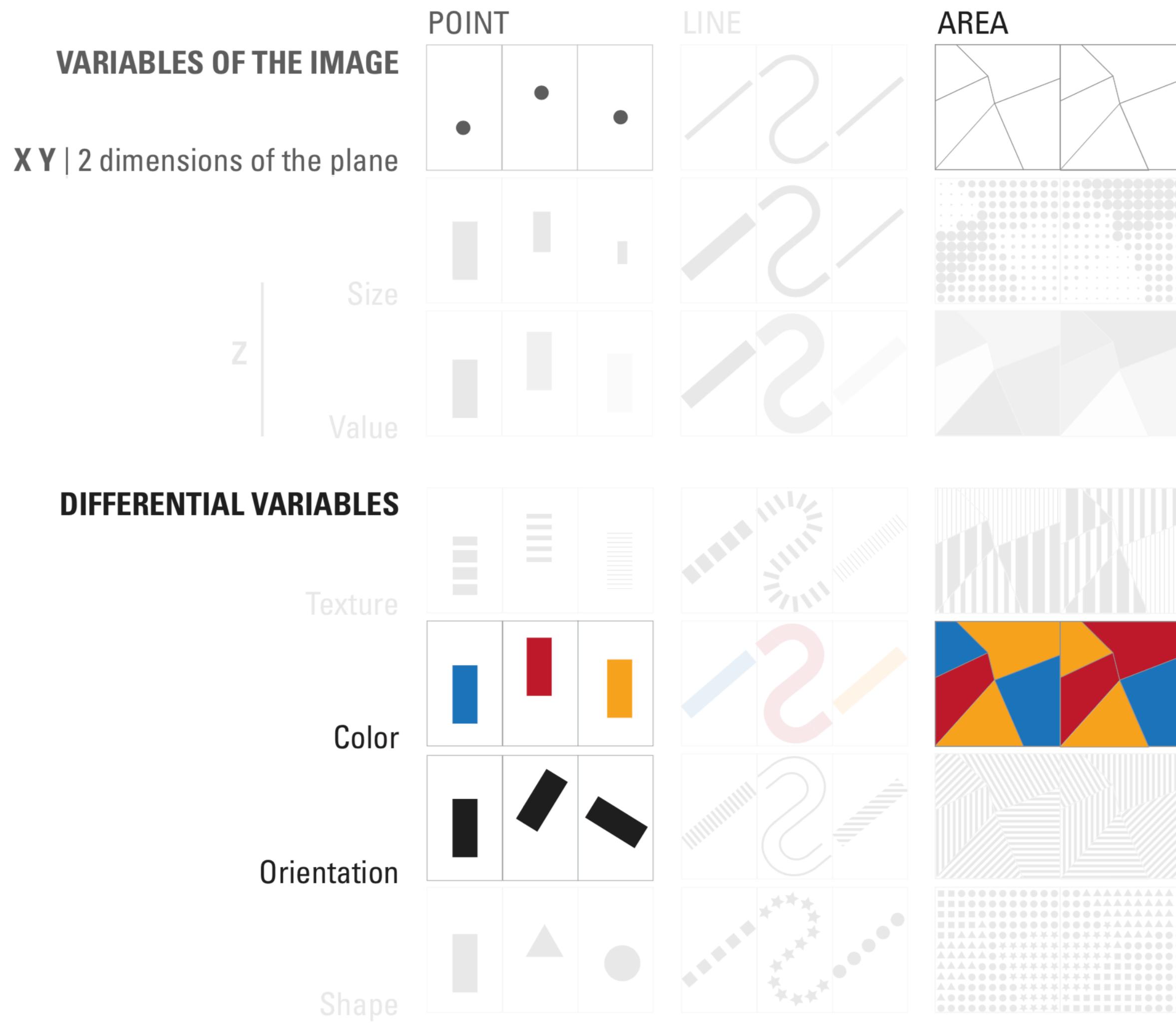
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



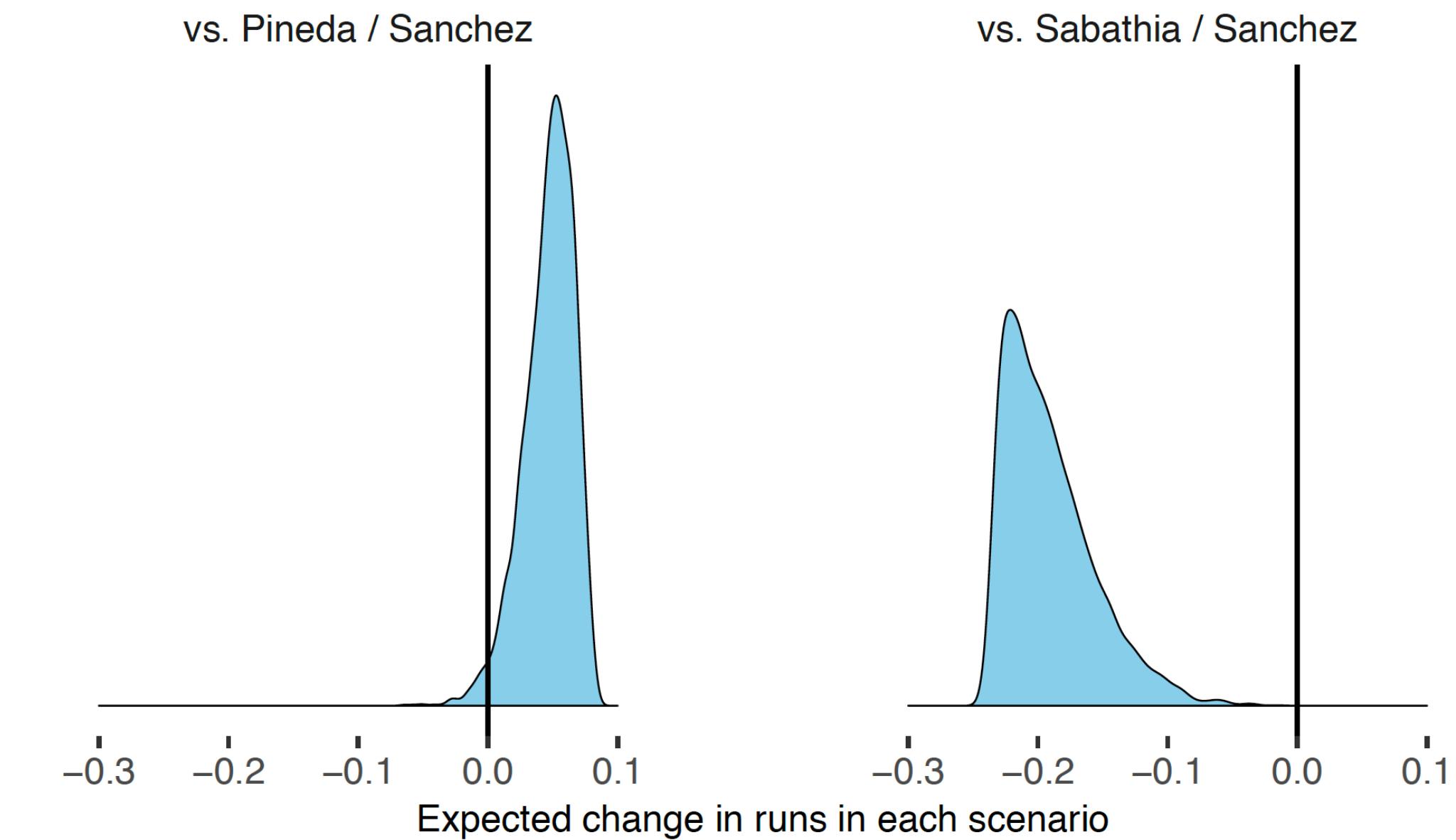
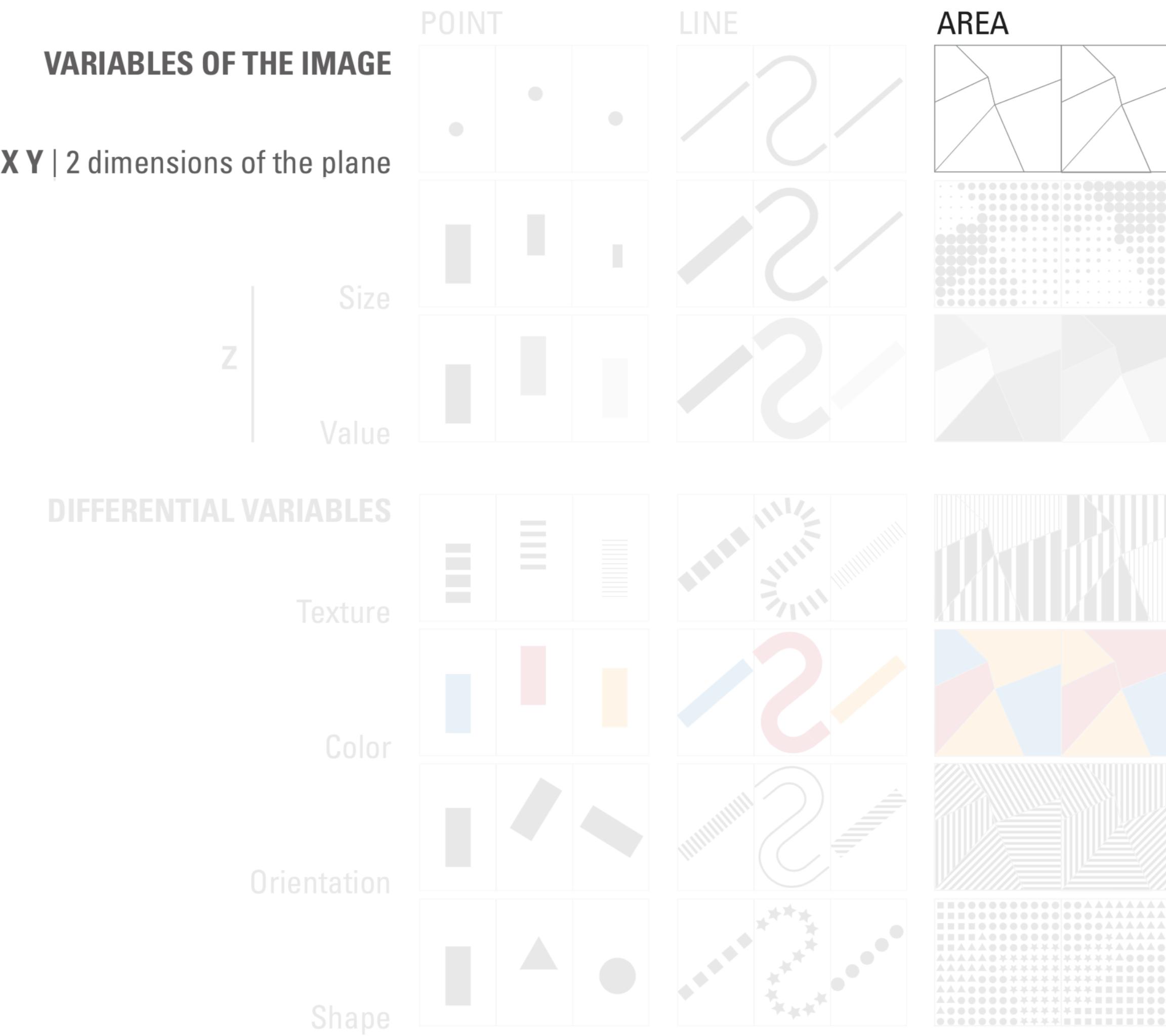
data encodings, visual channels for encoding data

Citi Bike example — *exploratory data analysis*



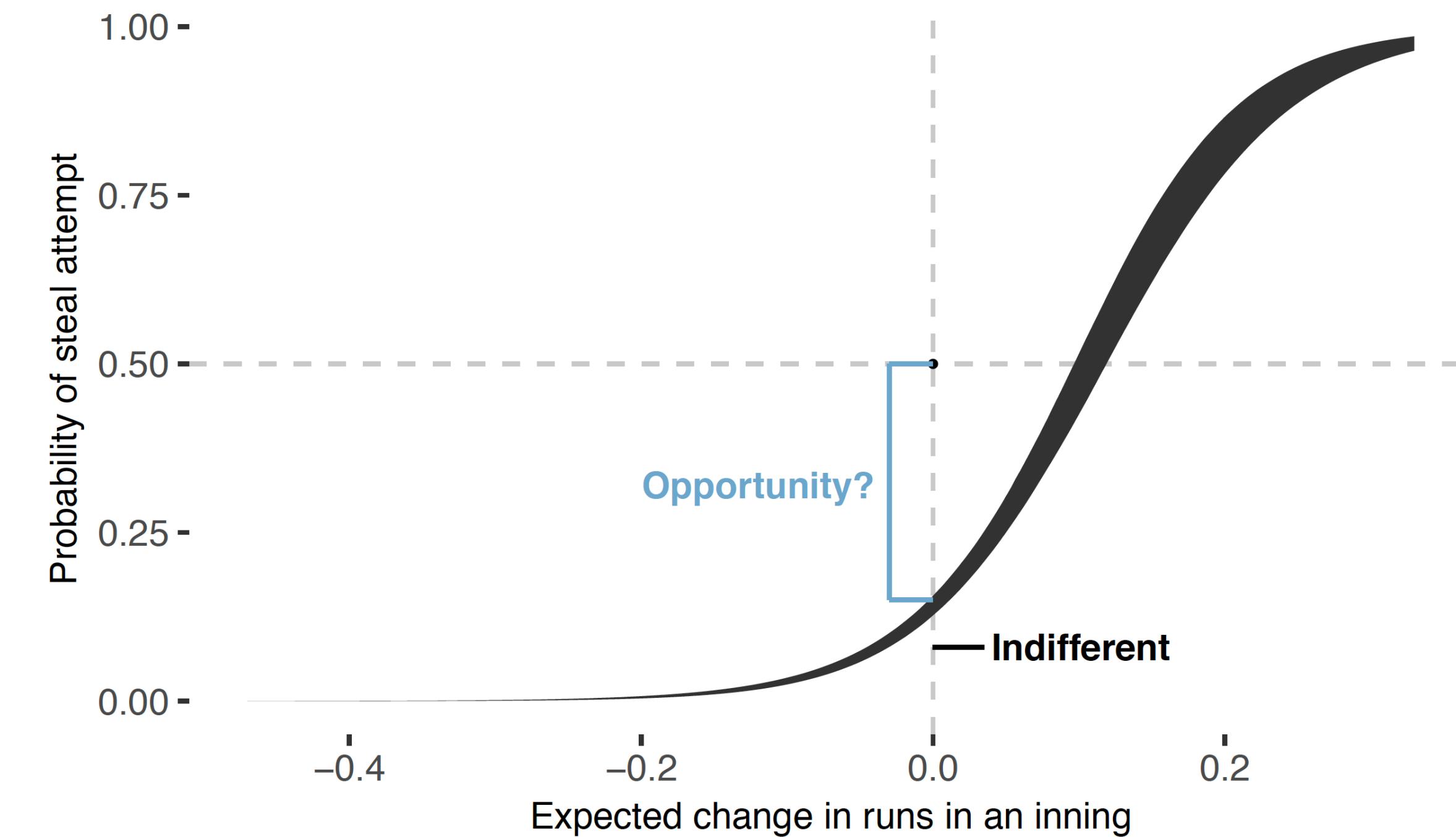
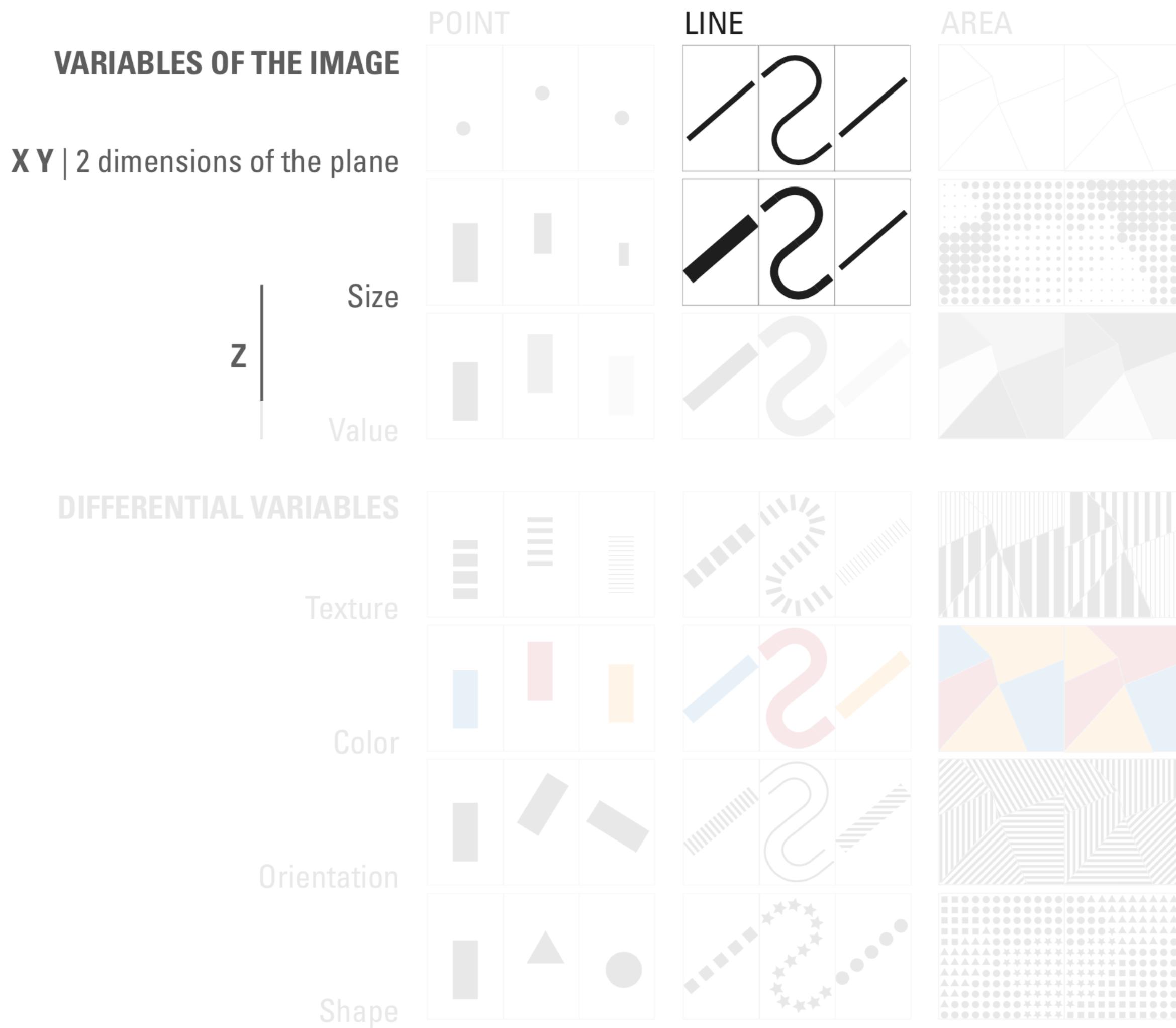
data encodings, visual channels for encoding data

Dodgers draft proposal example



data encodings, visual channels for encoding data

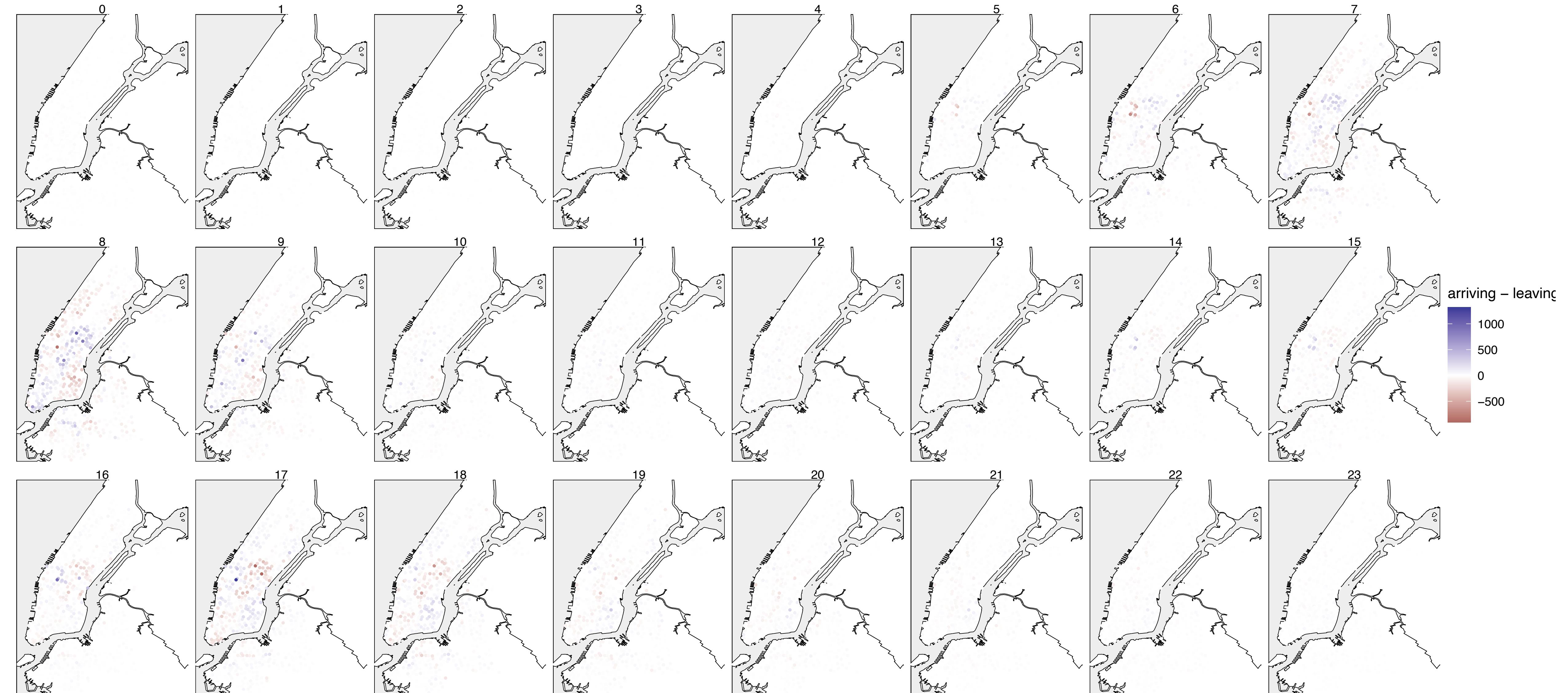
Dodgers *draft* proposal example



adding dimensions through small multiples

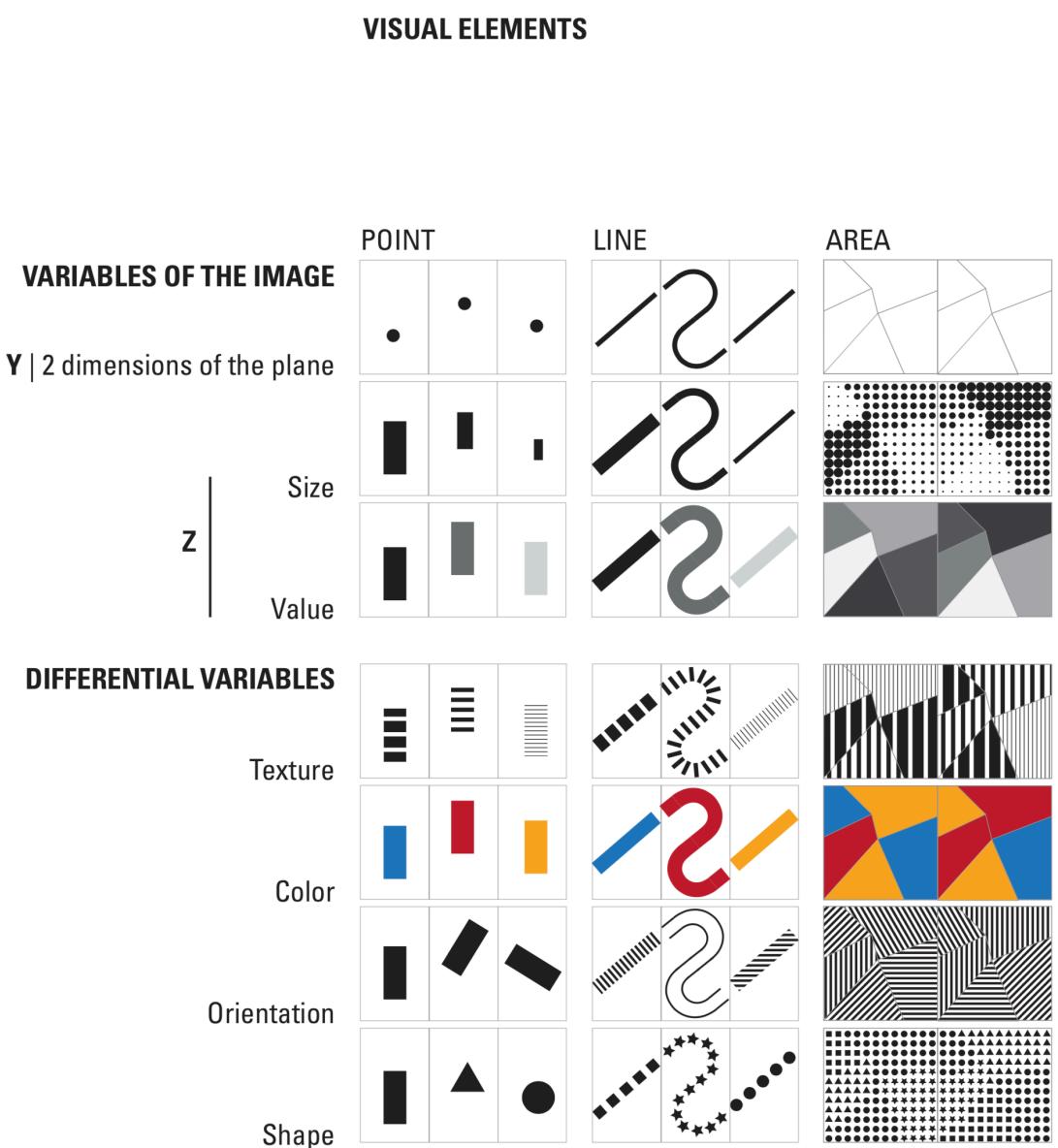
data encodings, small multiples (of area + color + point + value)

Citi Bike example — *exploratory data analysis*



class exercises

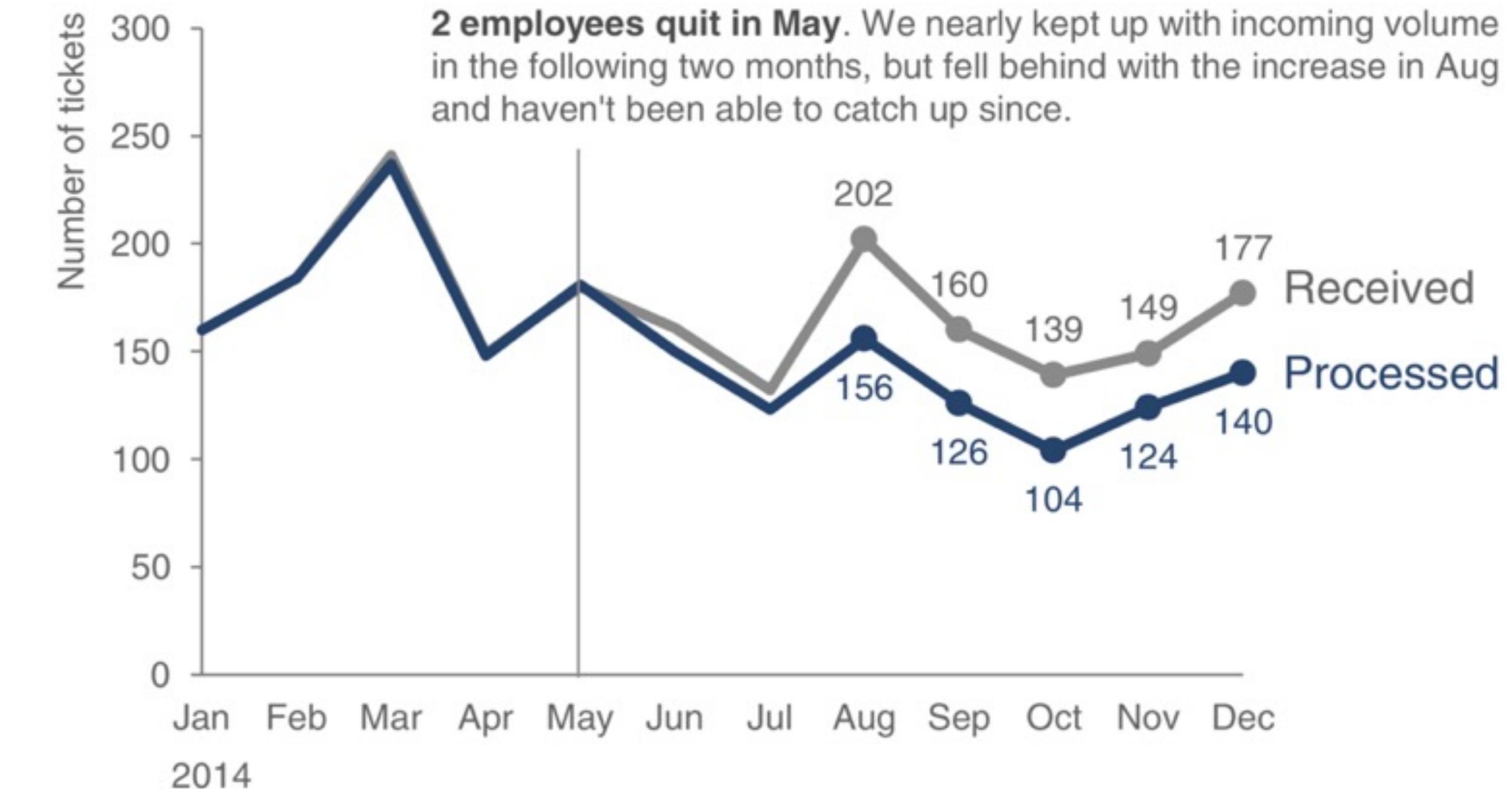
exercise, identify data encodings in visual channels



Please approve the hire of 2 FTEs

to backfill those who quit in the past year

Ticket volume over time

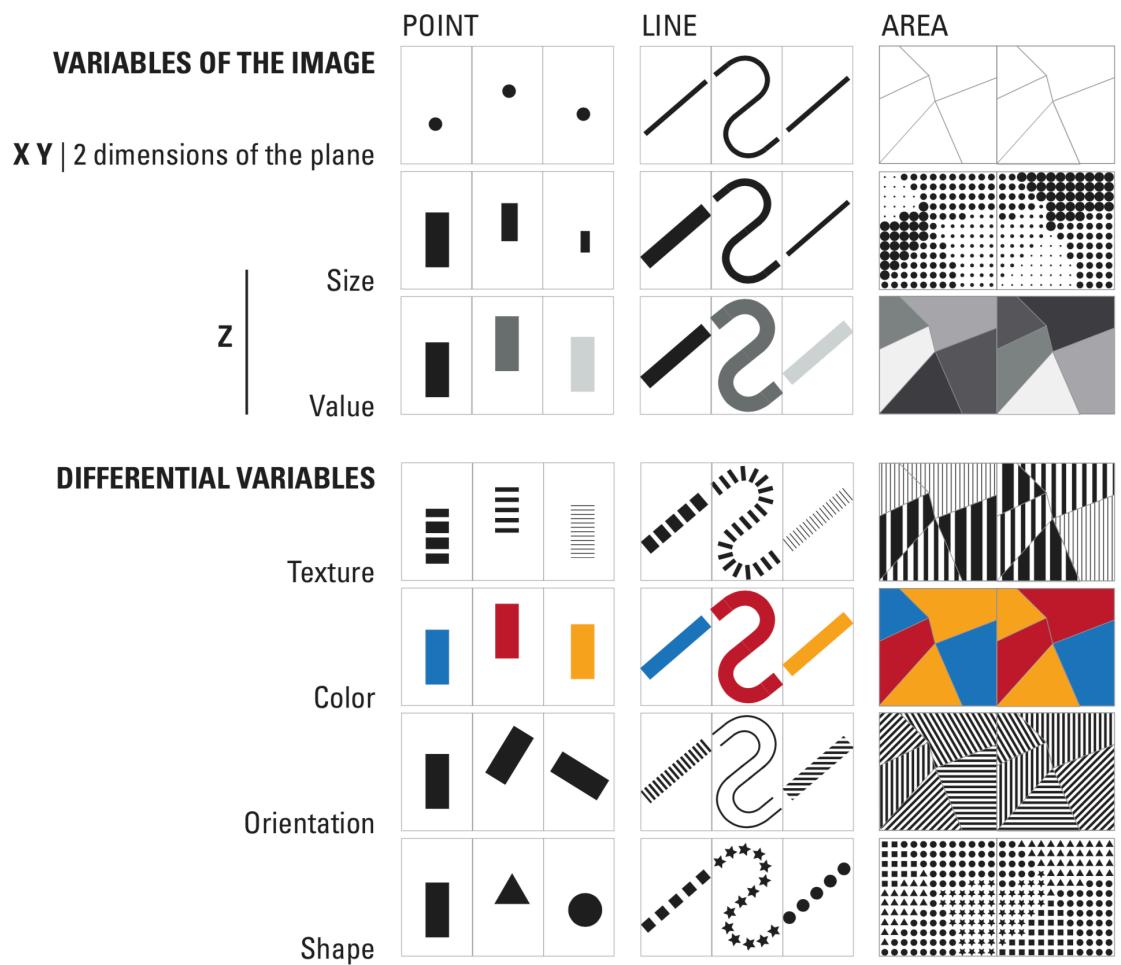


Data source: XYZ Dashboard, as of 12/31/2014 | A detailed analysis on tickets processed per person and time to resolve issues was undertaken to inform this request and can be provided if needed.

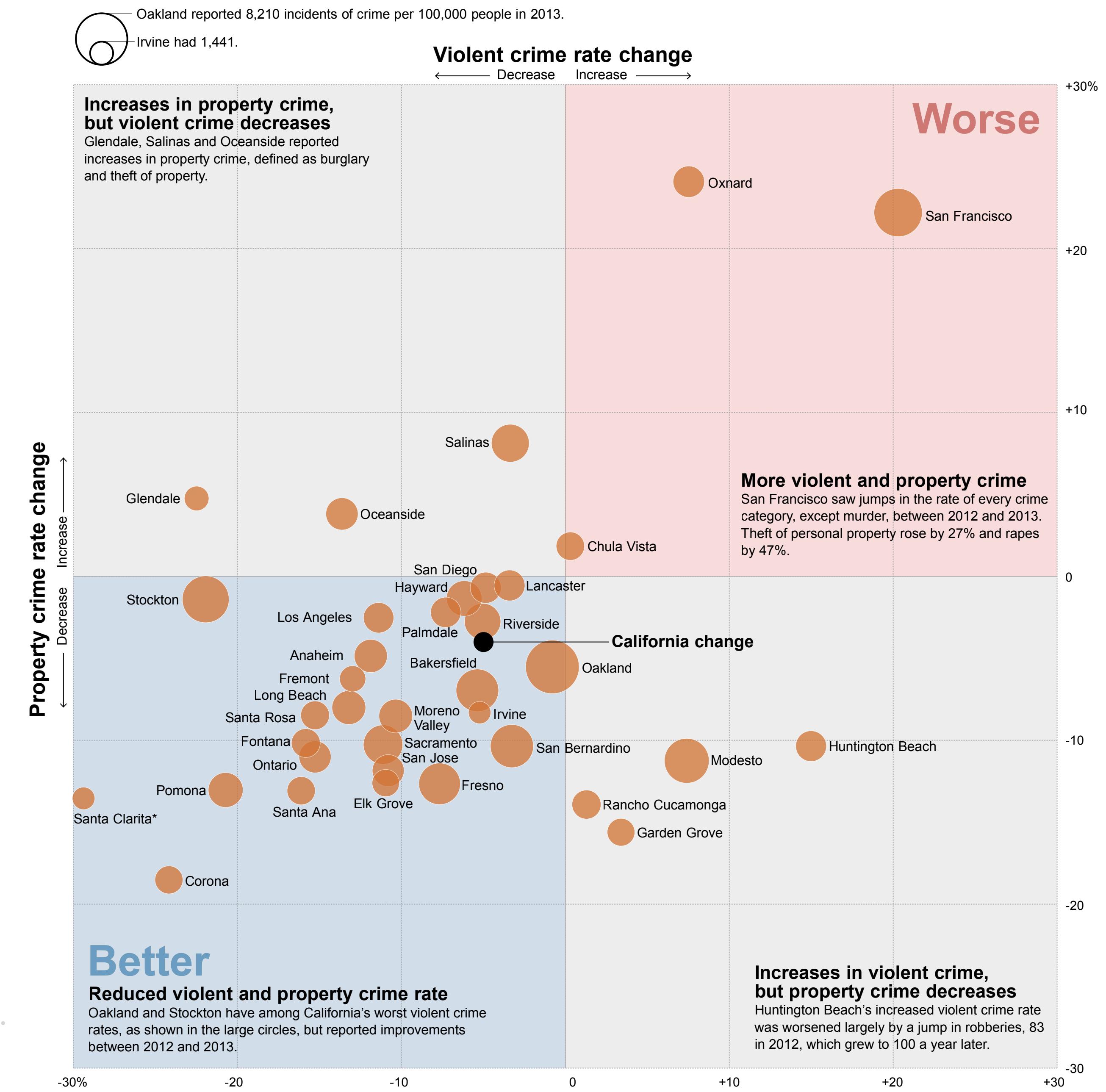
— Knaflic, Cole Nussbaumer. *Storytelling with Data. A Data Visualization Guide for Business Professionals*. Wiley, 2015.

exercise, identify data encodings in visual channels

VISUAL ELEMENTS

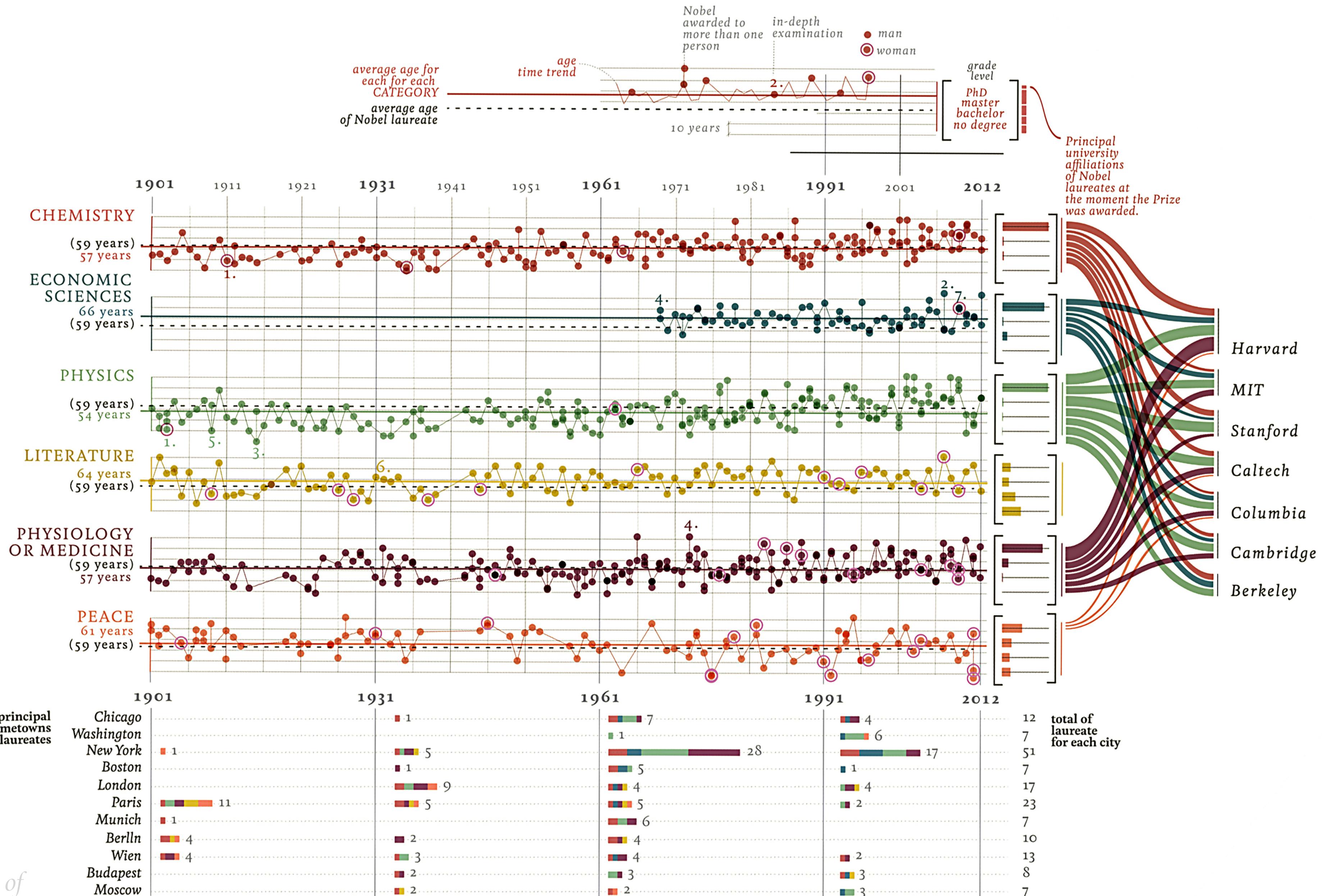
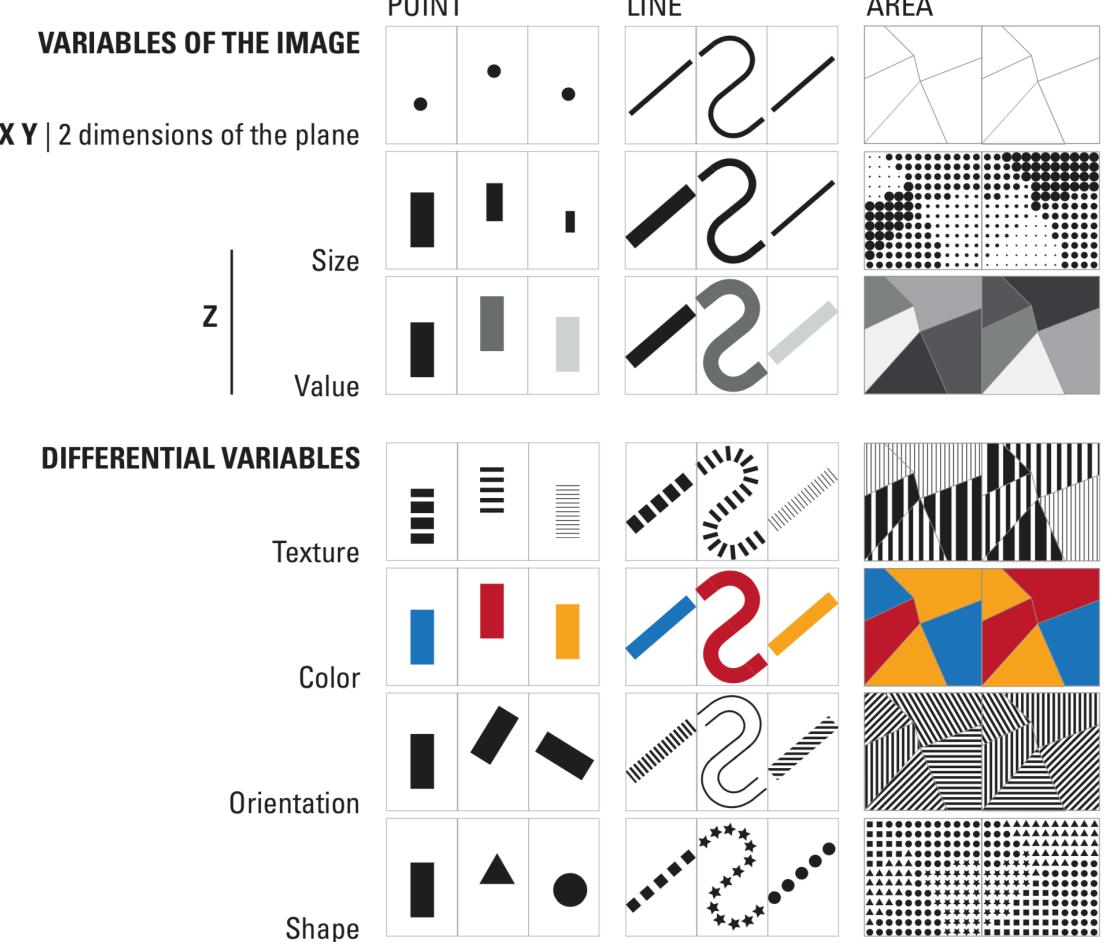


Schleuss, Jon, and Rong-Cong Lin II. 2013.
“California Crime 2013.” Los Angeles Times.



exercise, identify data encodings in visual channels

VISUAL ELEMENTS

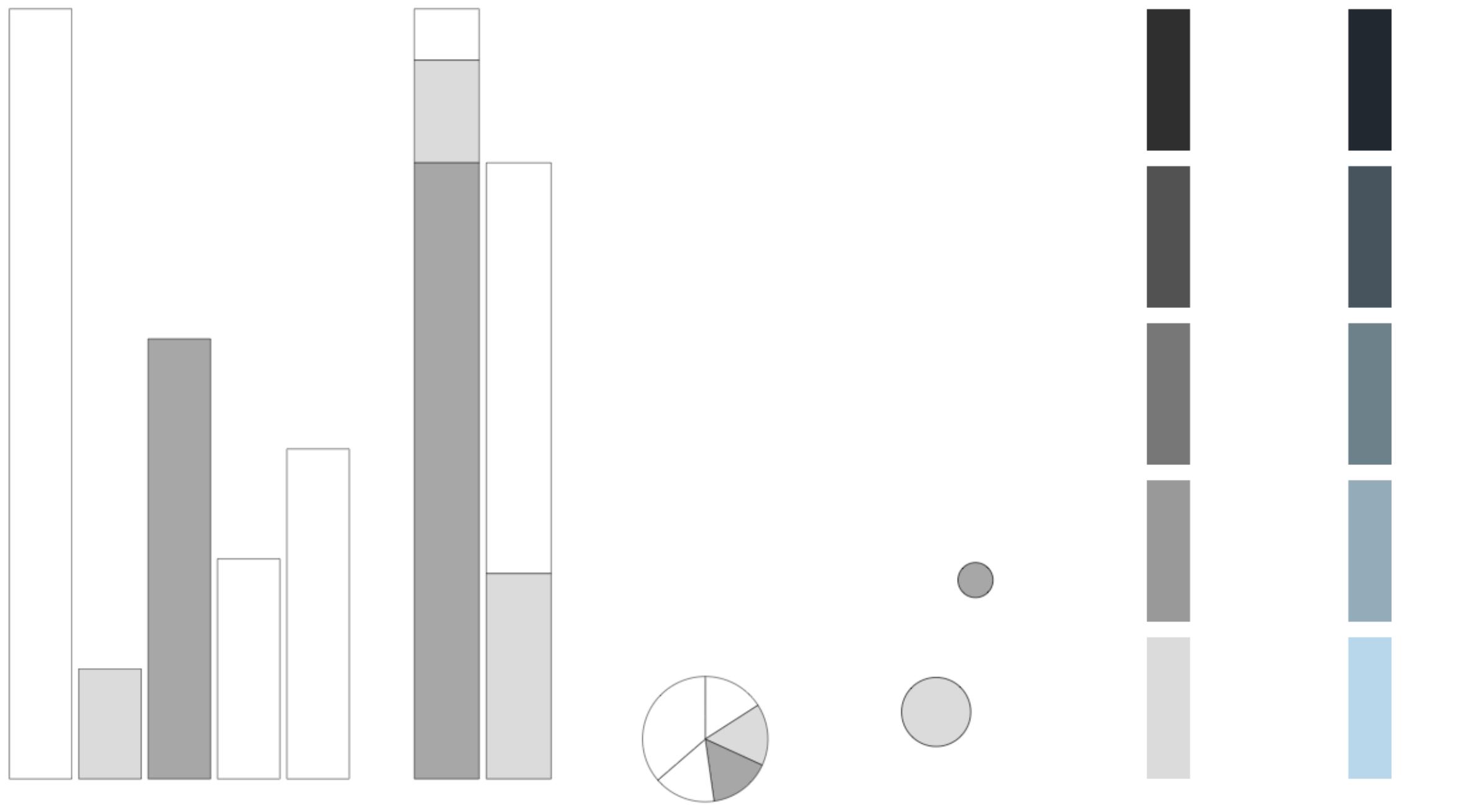


Spencer, Scott. *Approximating the Components of Lupi's Nobels, No Degrees*. March 15, 2019. <https://ssp3nc3r.github.io/post/approximating-the-components-of-lupi-s-nobel-no-degrees/>.

channel effectiveness for encoding data

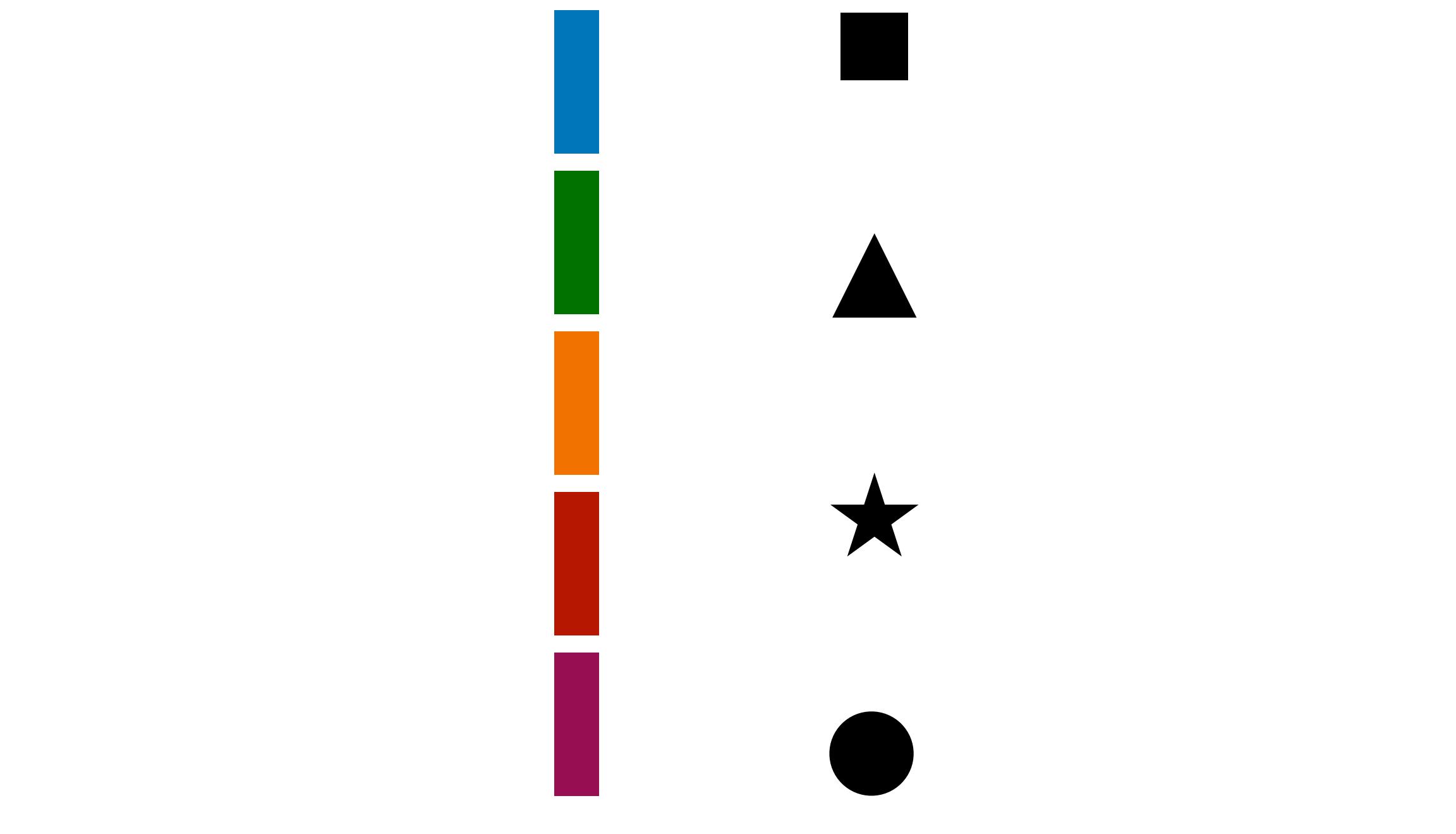
general channel effectiveness, encoding data

ratio, interval, and ordered



more effective ← → less effective

categorical

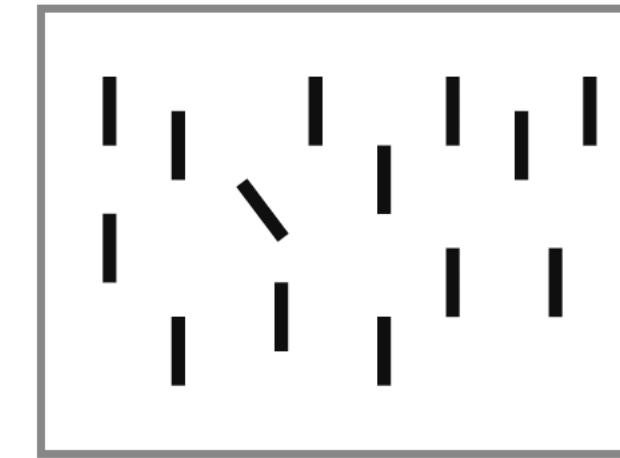


more effective ← → less effective

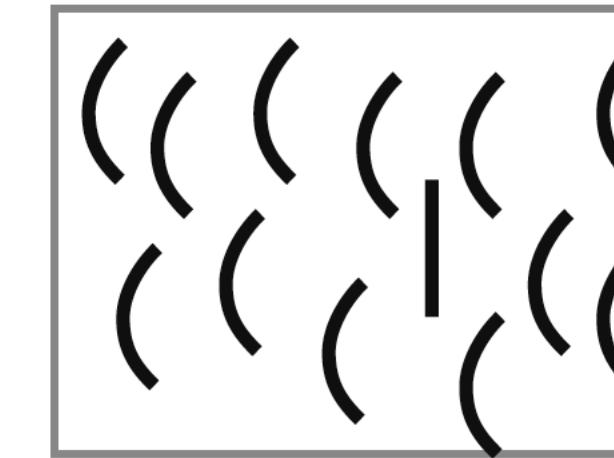
perceptual psychology

perceptual psychology, *pre-attentive attributes*

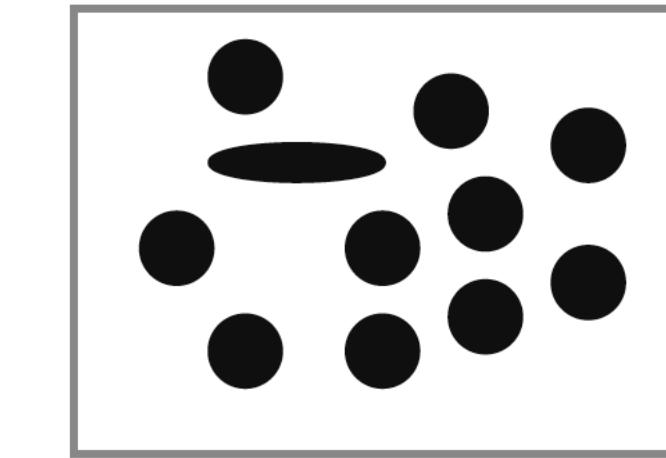
Orientation



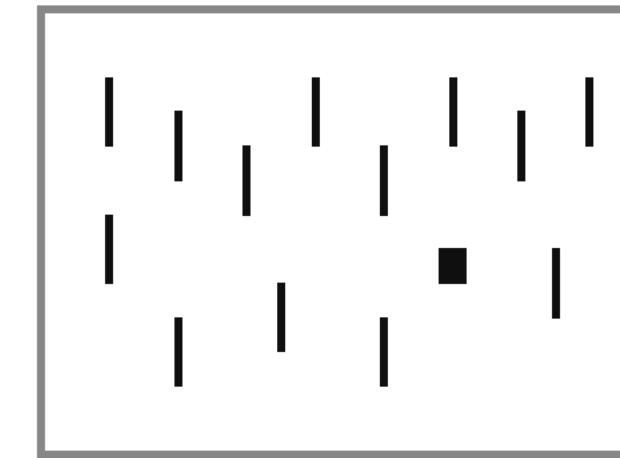
Curved straight



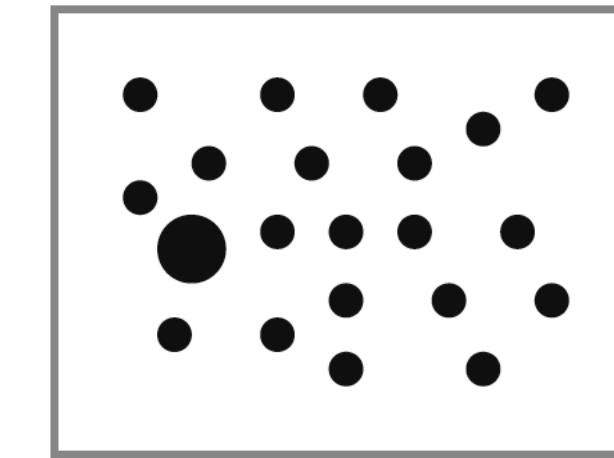
Shape



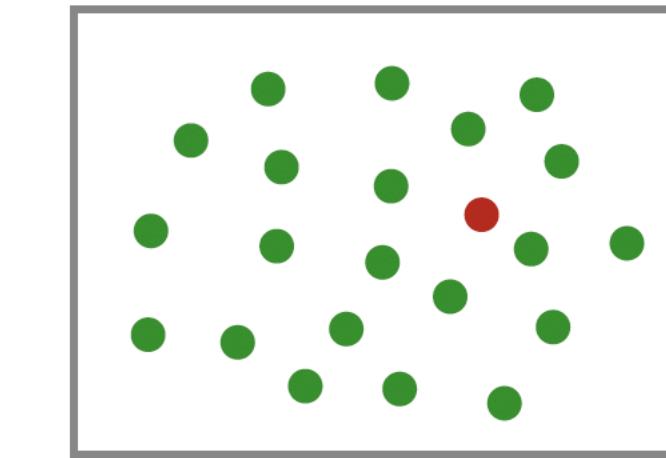
Shape



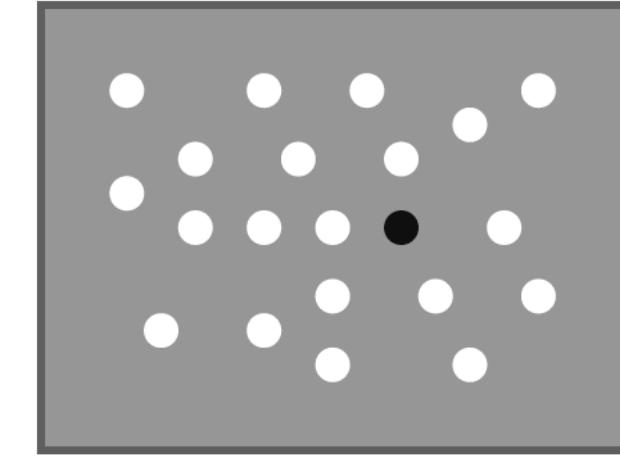
Size



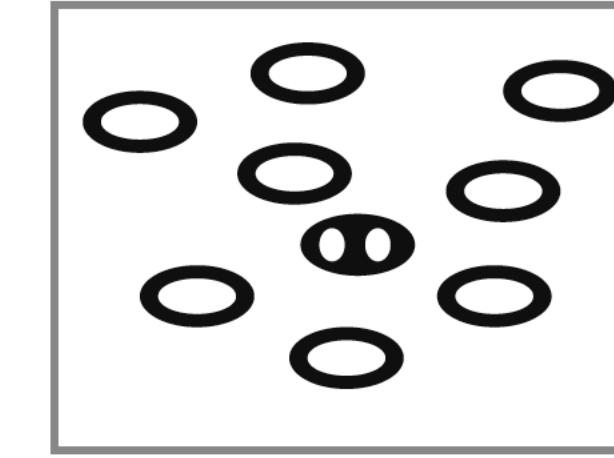
Color



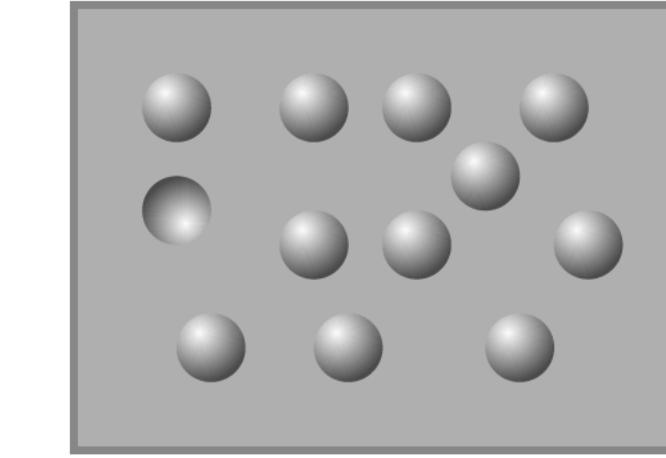
Light/dark



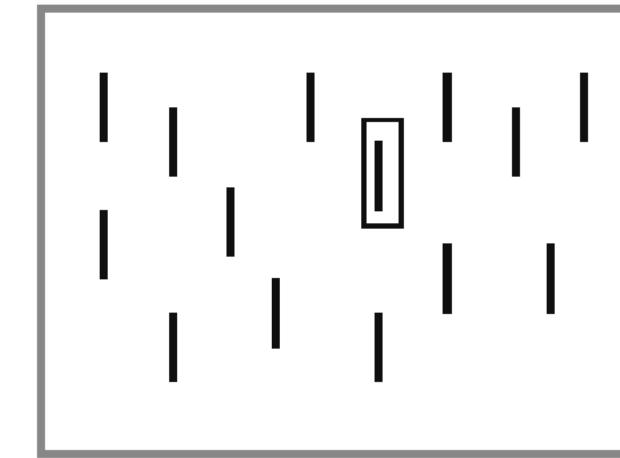
Topology (or count)



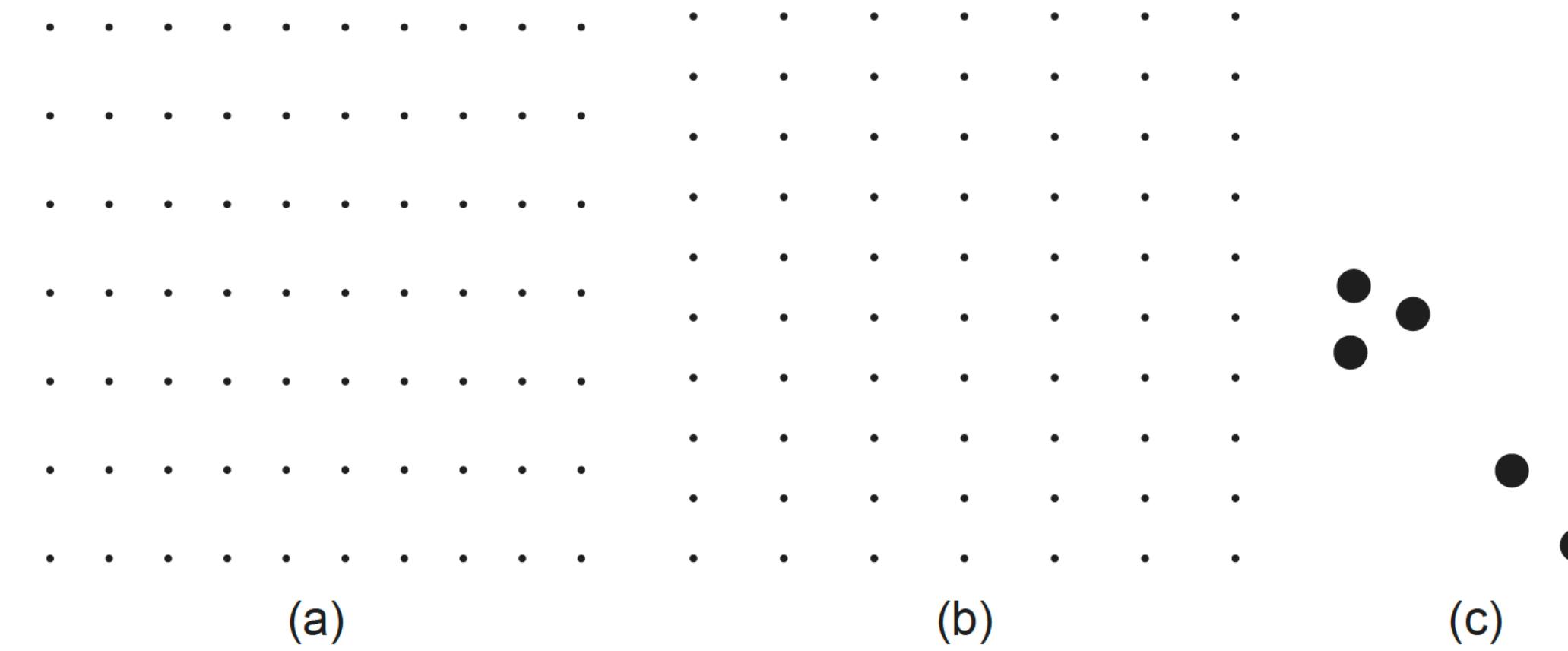
Convex/concave



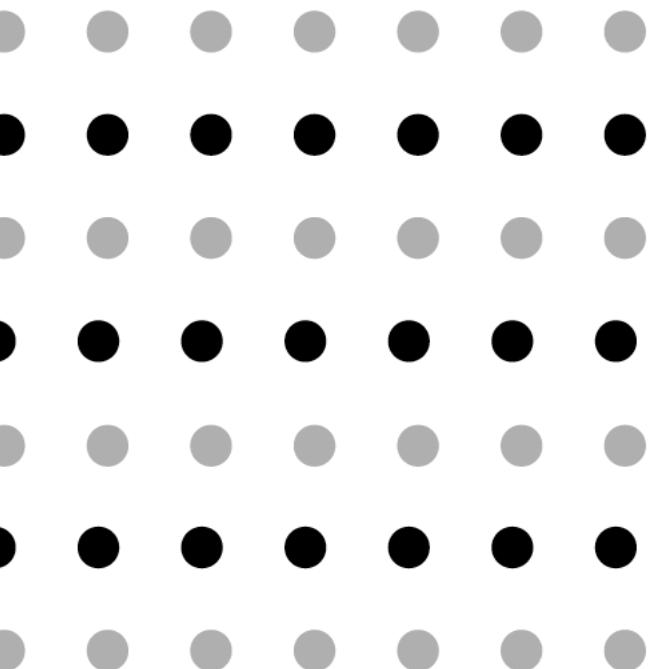
Addition



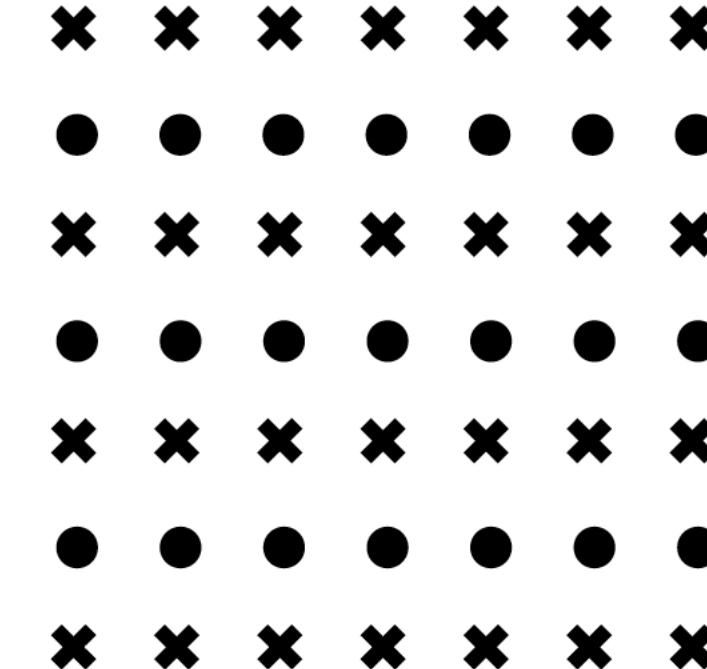
perceptual psychology, Gestalt principles, *proximity*



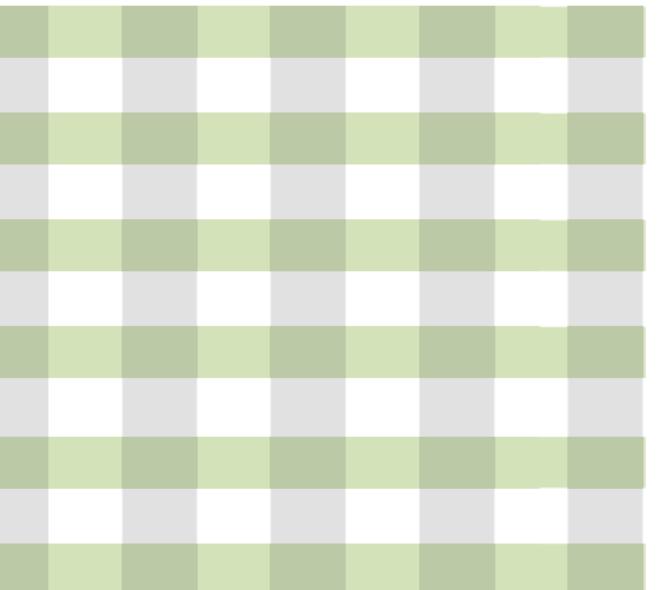
perceptual psychology, Gestalt principles, *similarity*



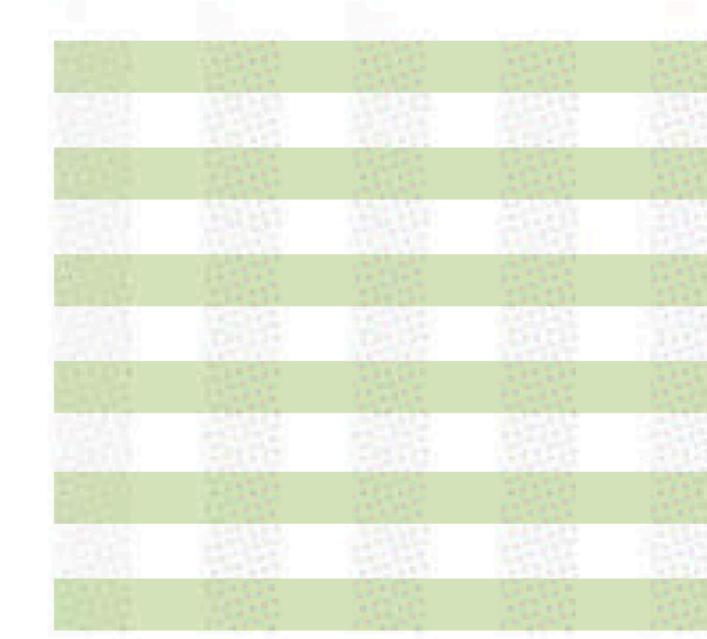
(a)



(b)

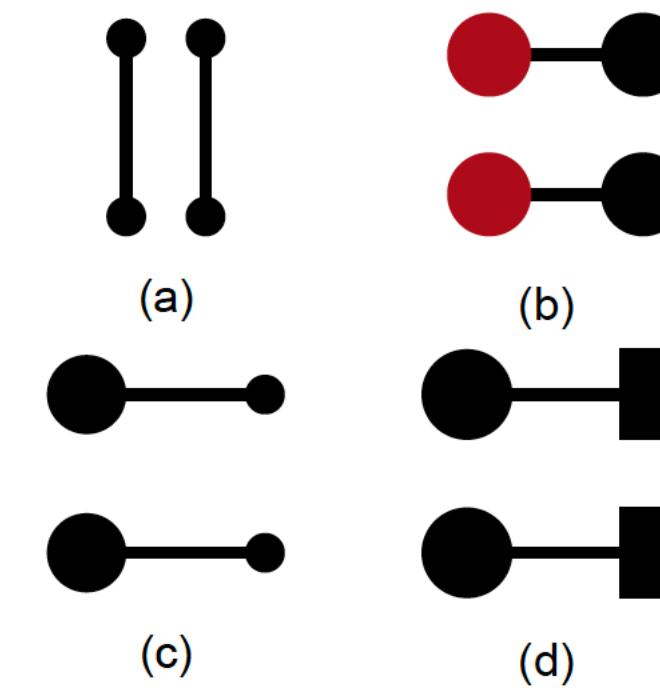


(c)

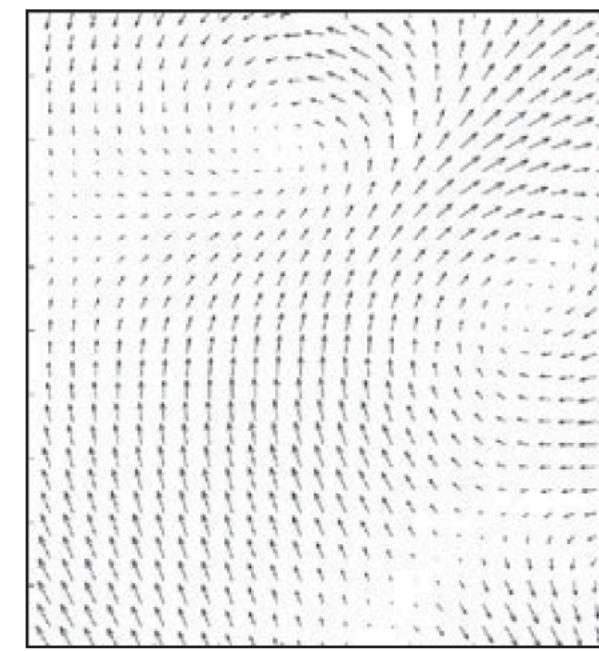


(d)

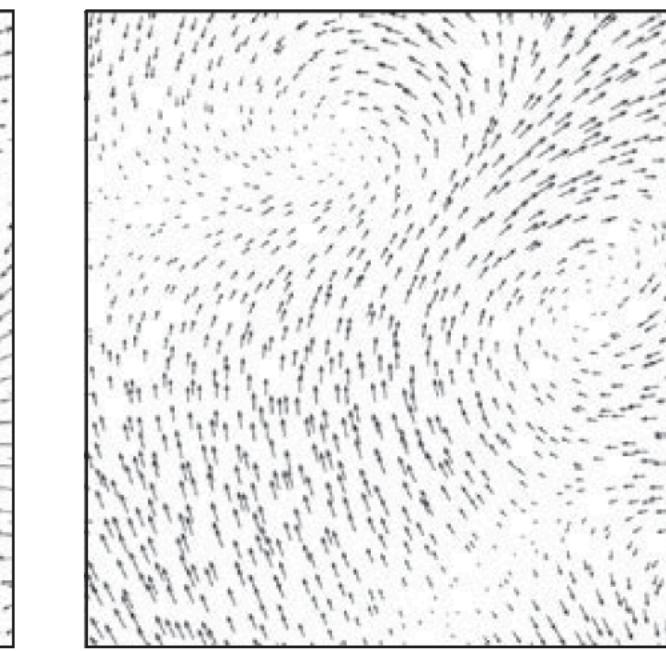
perceptual psychology, Gestalt principles, *connectedness*



perceptual psychology, Gestalt principles, *orientation*, *magnitude*, *direction*



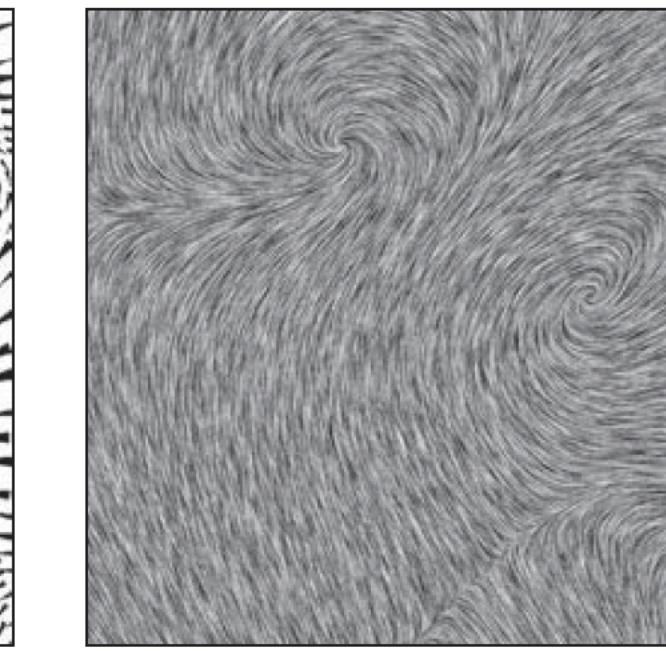
(a)



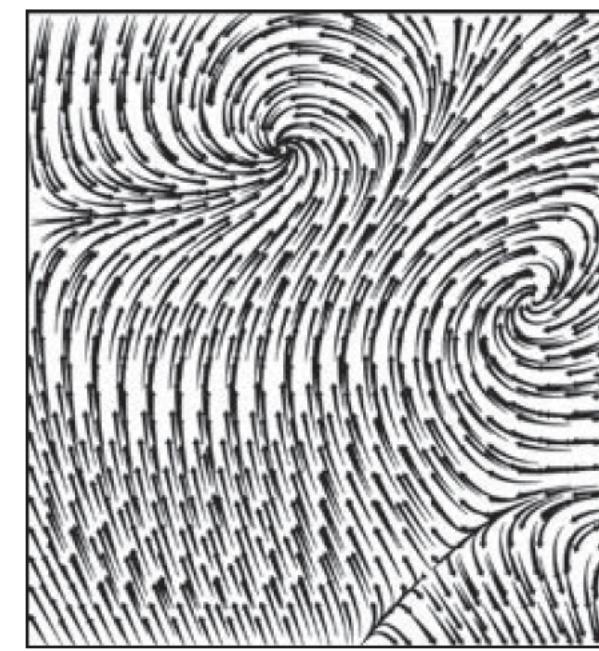
(b)



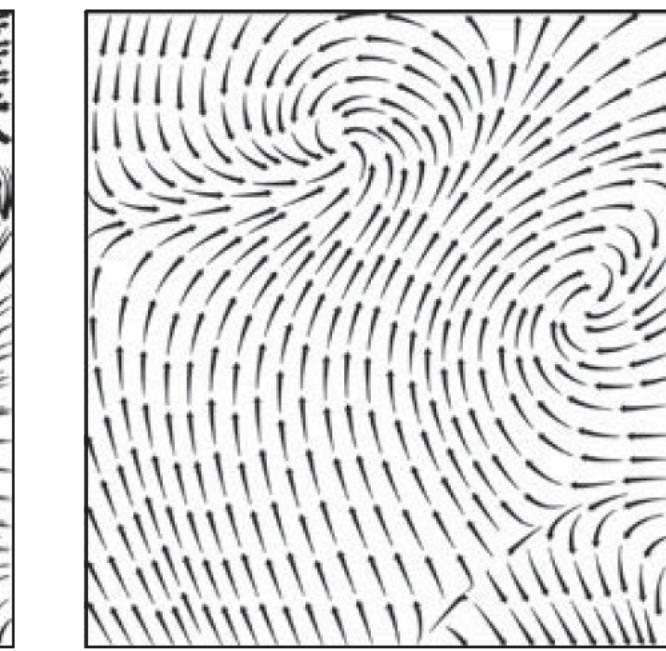
(c)



(d)



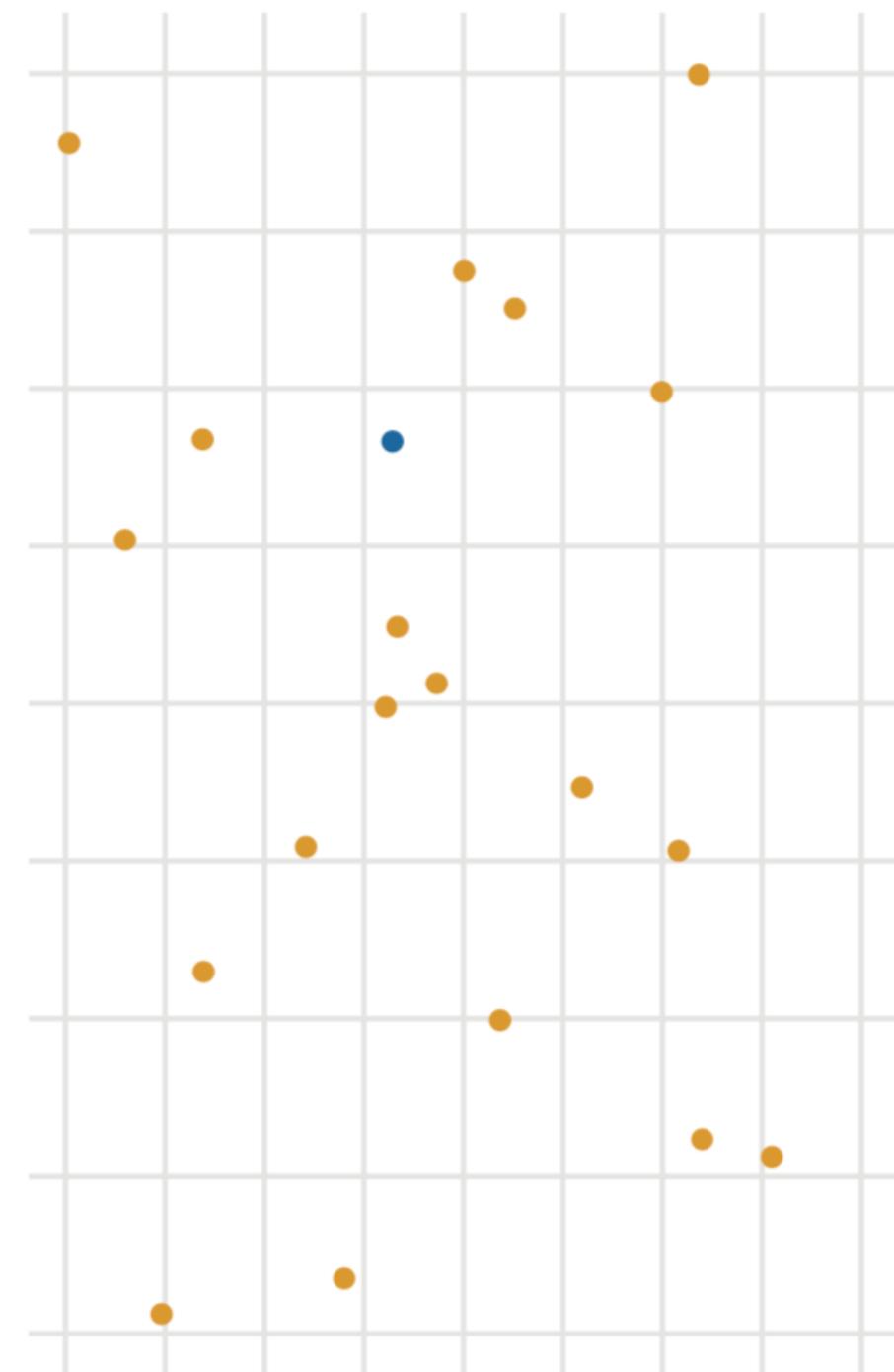
(e)



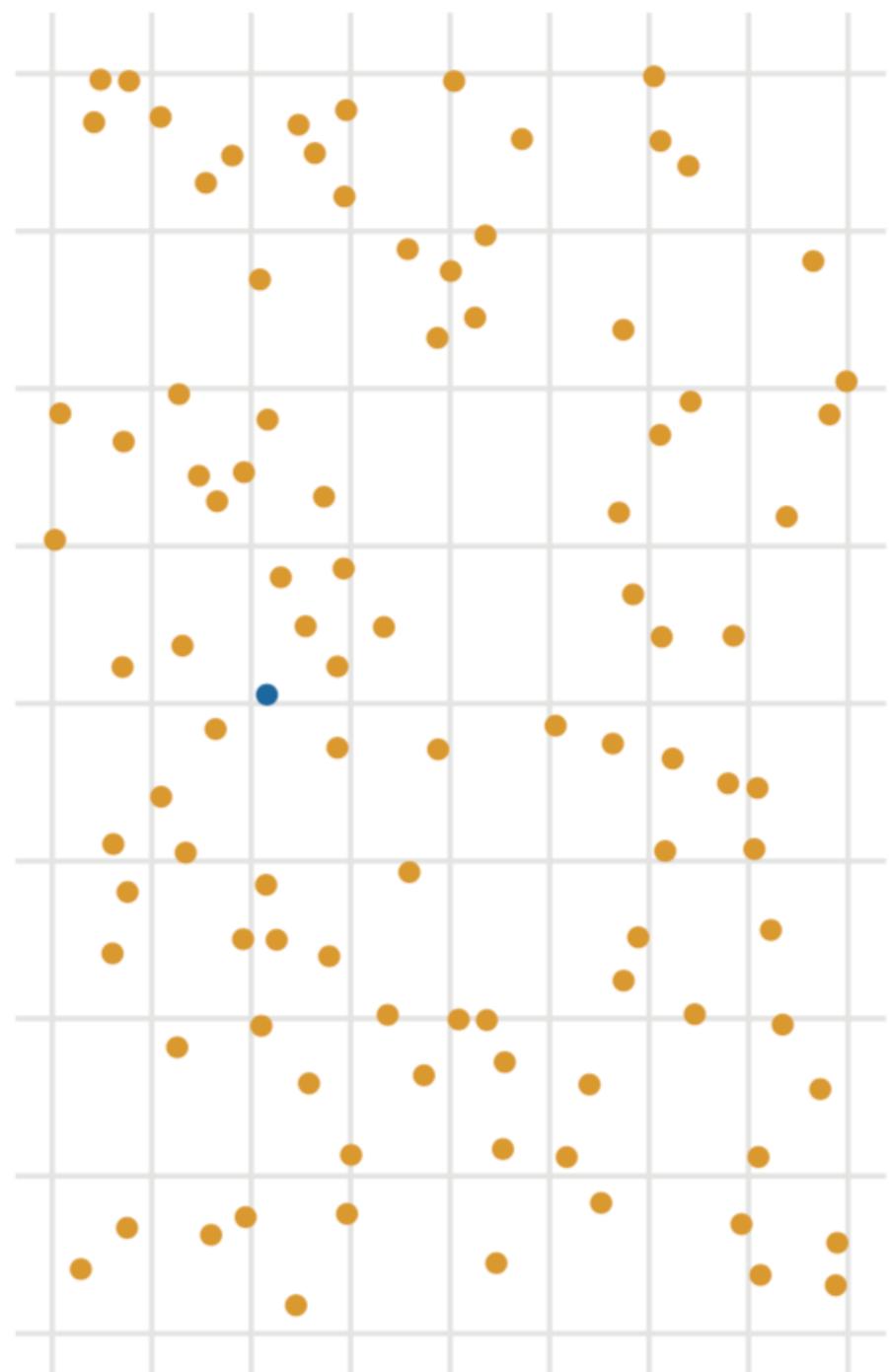
(f)

perceptual psychology, example — *focusing visual attention*

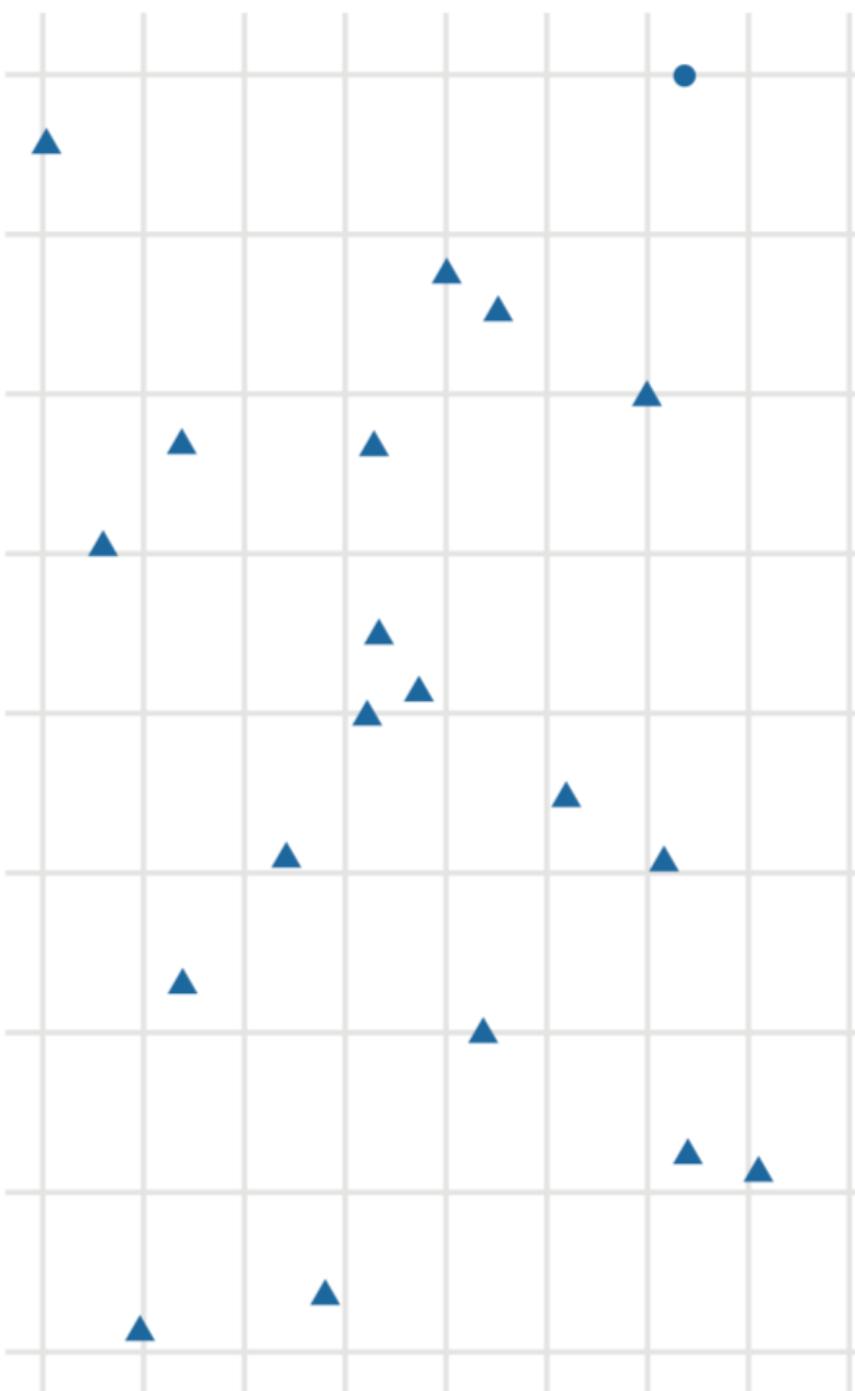
Color only, $N = 20$



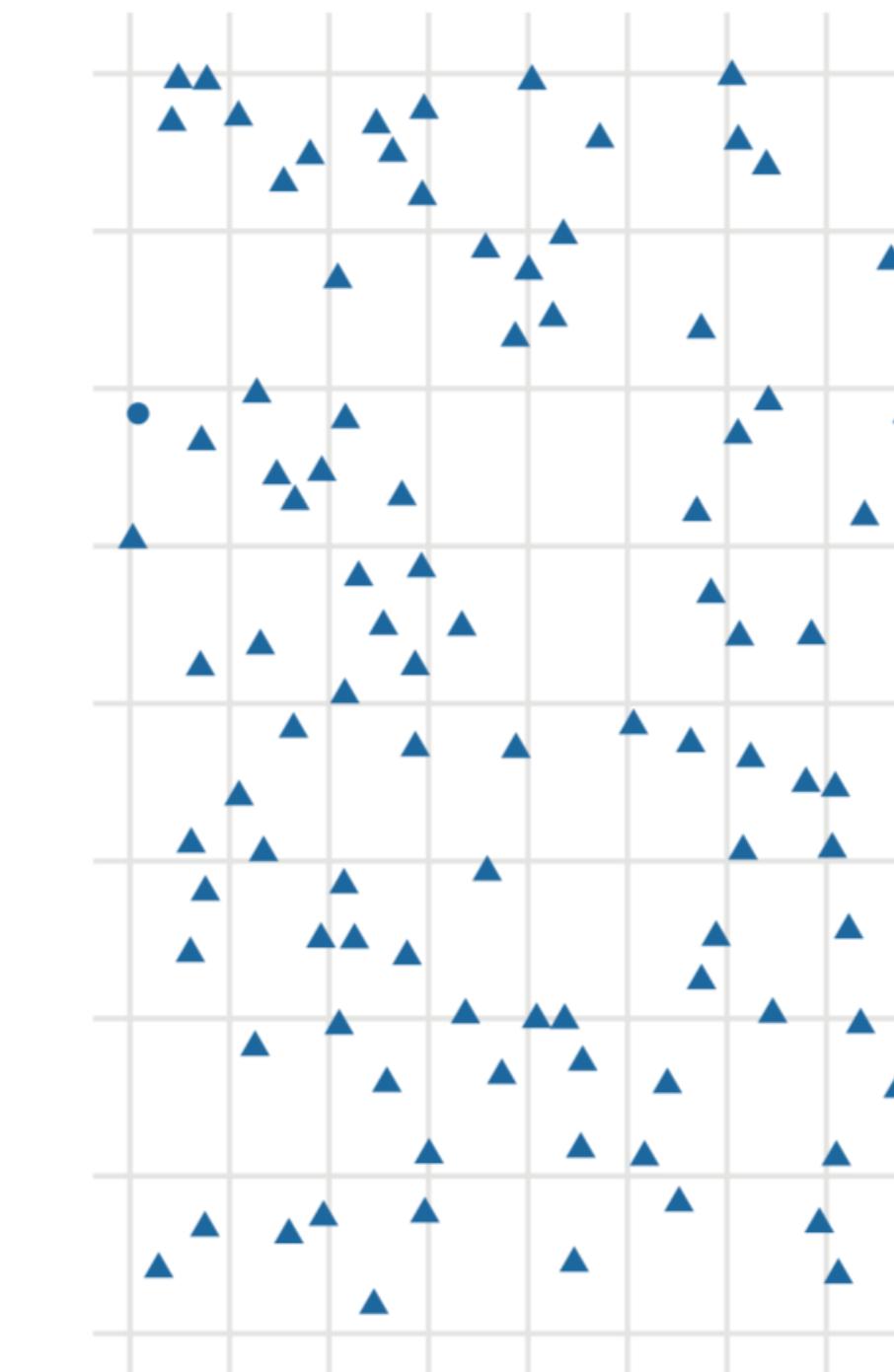
Color only, $N = 100$



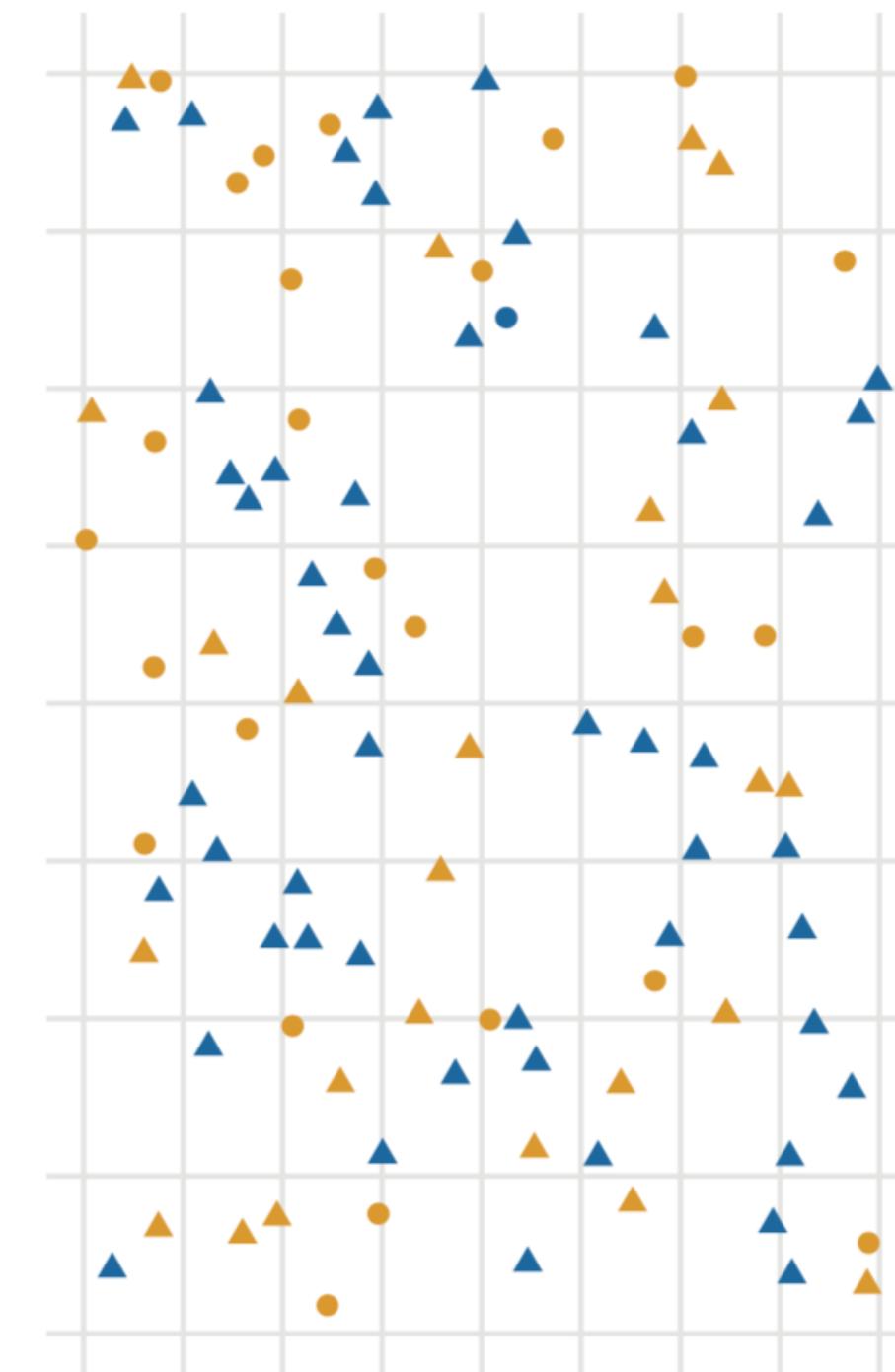
Shape only, $N = 20$



Shape only, $N = 100$

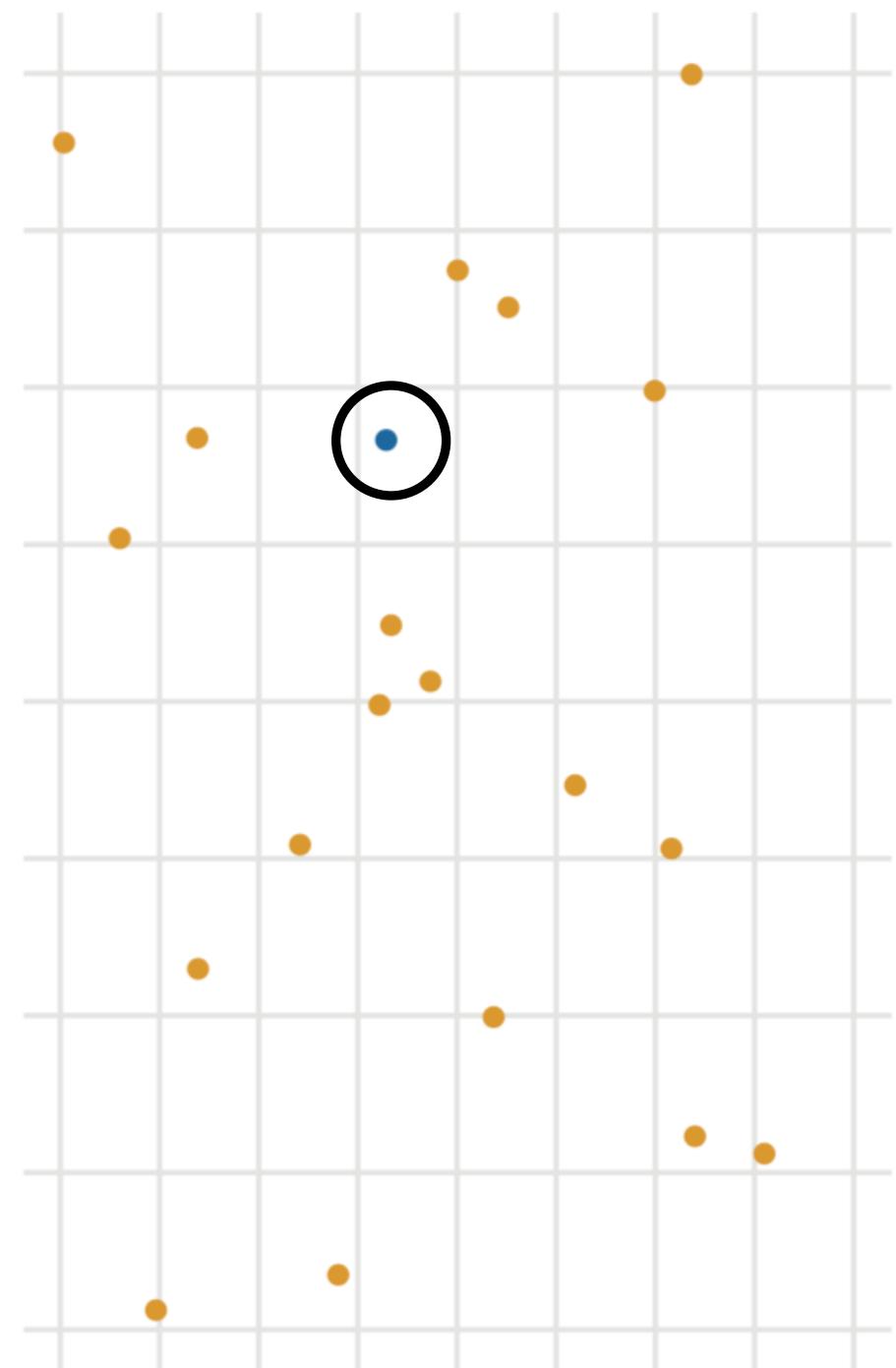


Color & shape, $N = 100$

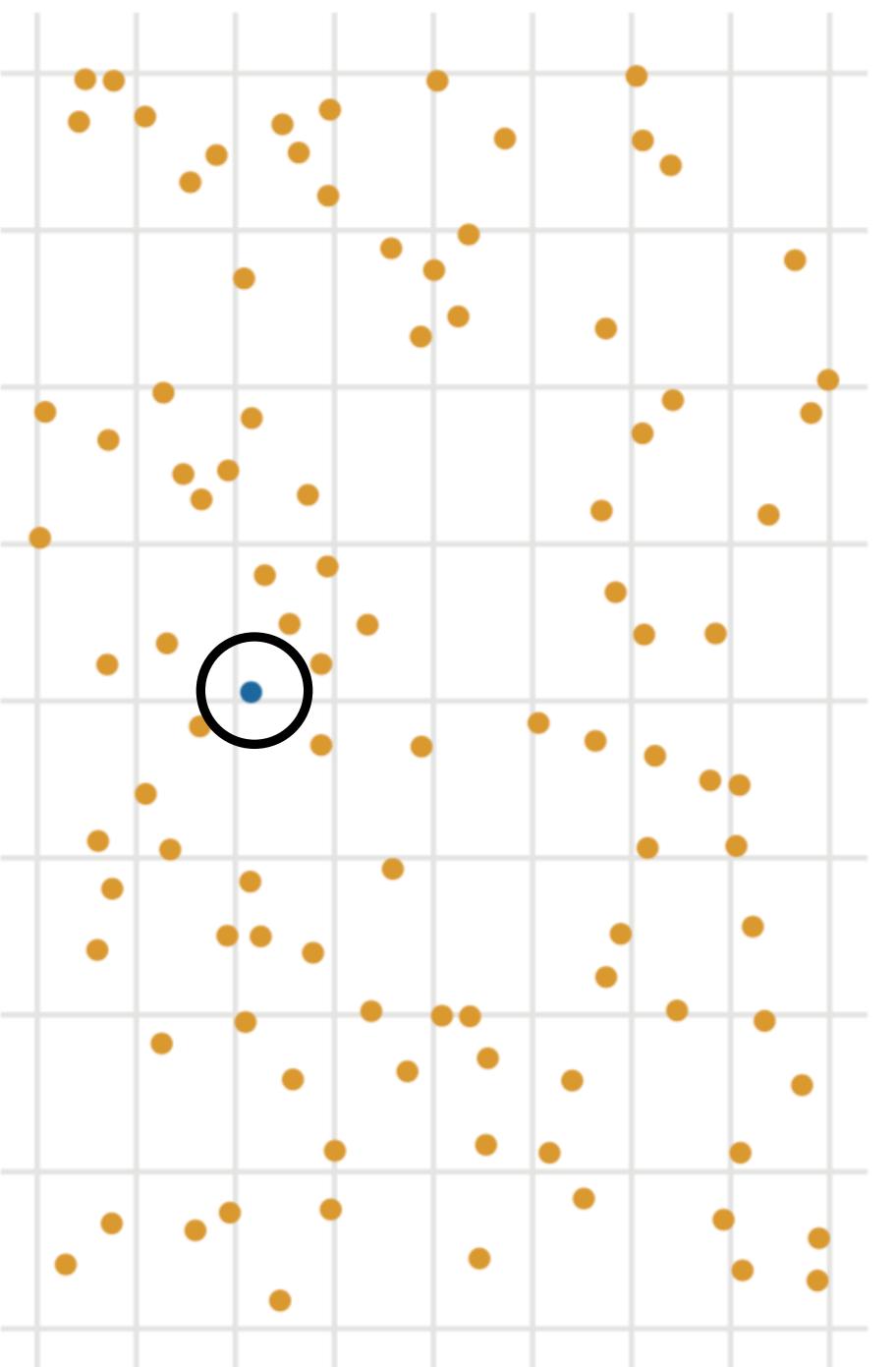


perceptual psychology, example — *focusing visual attention*

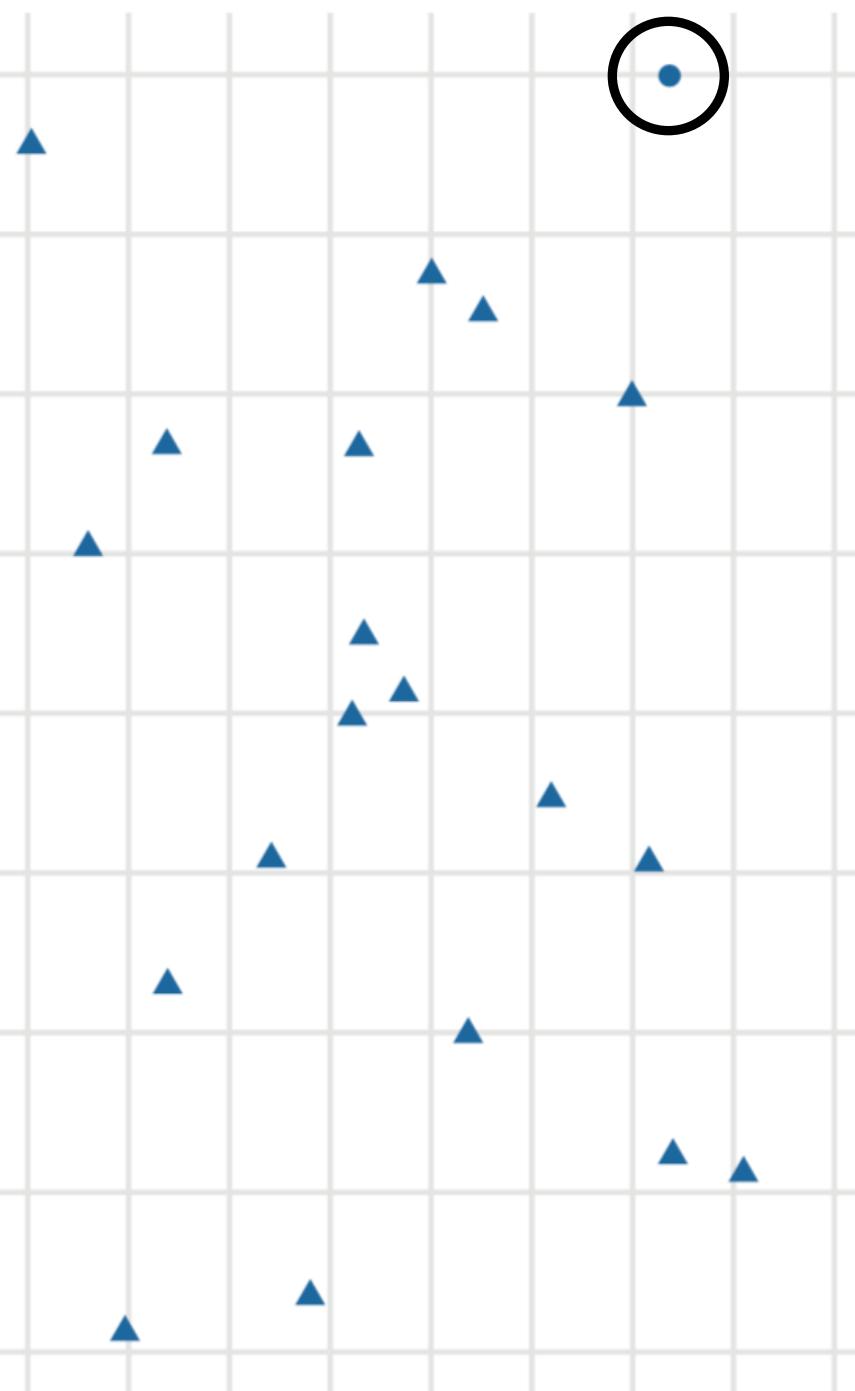
Color only, $N = 20$



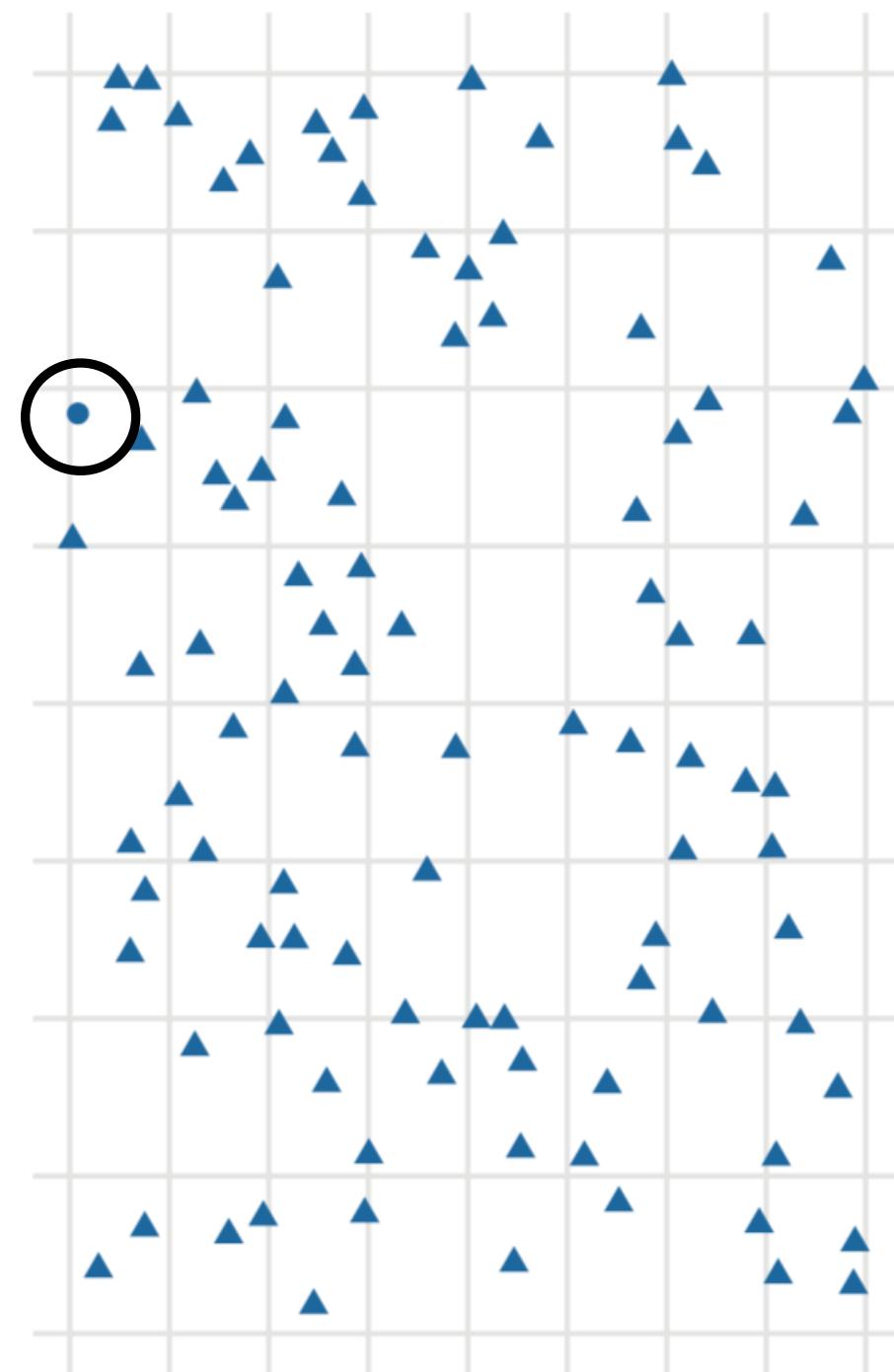
Color only, $N = 100$



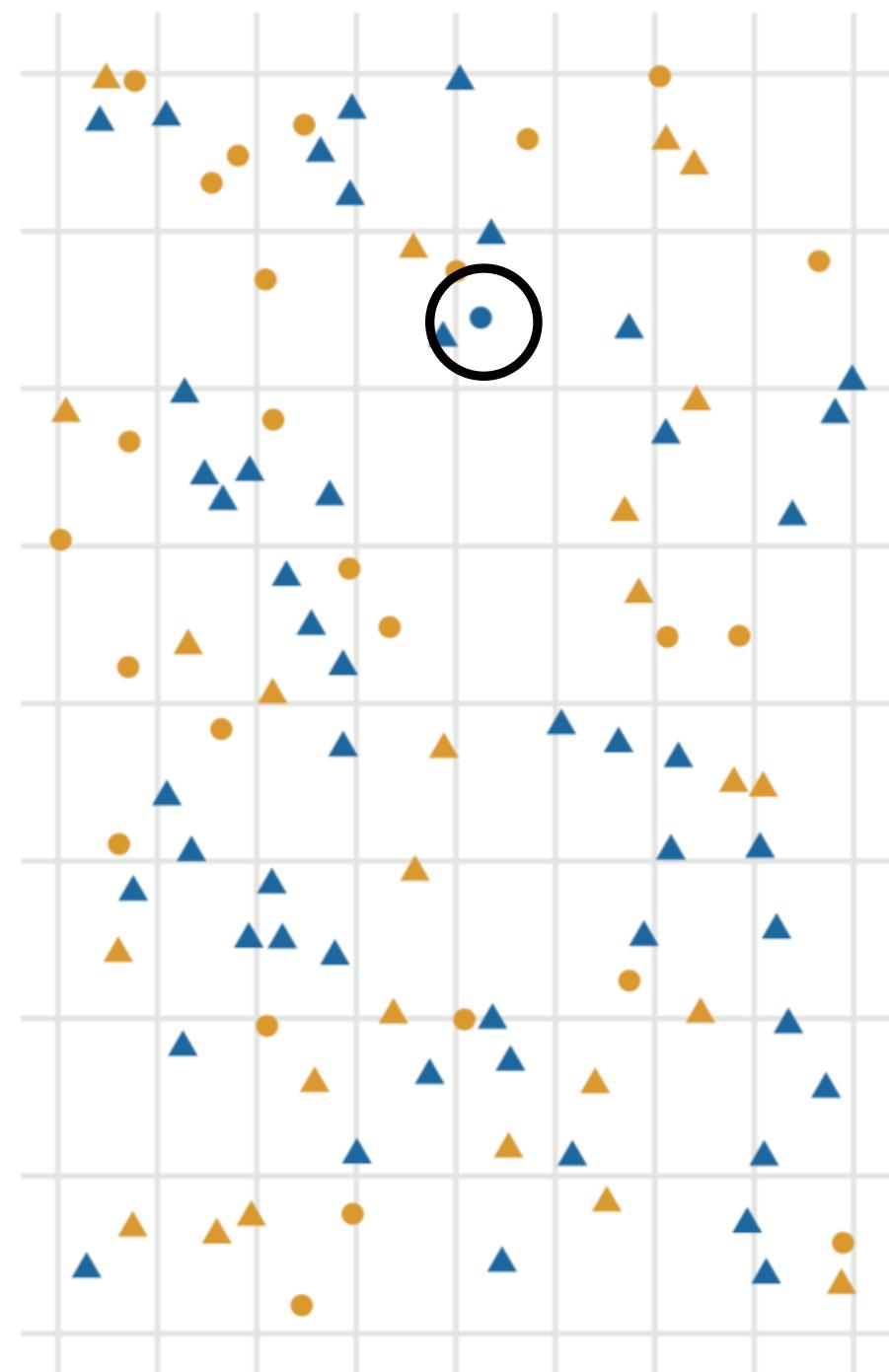
Shape only, $N = 20$



Shape only, $N = 100$



Color & shape, $N = 100$



resources

References

- Spencer**, Scott. "Visual, Sec. 2-2.1.3" In *Data in Wonderland*. 2021. https://ssp3nc3r.github.io/data_in_wonderland.
-
- Anderson**, E. W., K. C. Potter, L. E. Matzen, J. F. Shepherd, G. A. Preston, and C. T. Silva. "A User Study of Visualization Effectiveness Using EEG and Cognitive Load." *Computer Graphics Forum* 30, no. 3 (June 2011): 791–800.
- Anscombe**, F J. "Graphs in Statistical Analysis." *The American Statistician* 27, no. 1 (February 1973): 17–21.
- Bertin**, Jacques. *Semiology of Graphics: Diagrams Networks Maps*. Redlands: ESRI Press, 2010.
- Cleveland**, William S, and Robert McGill. "Graphical Perception: The Visual Decoding of Quantitative Information on Graphical Displays of Data." *Journal of the Royal Statistical Society. Series A* 150, no. 3 (1987): 192–229.
- . "Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods." *Journal of the American Statistical Association* 79, no. 387 (September 1984): 531–54.
- Harris**, Robert L. *Information Graphics: A Comprehensive Illustrated Reference*. New York: Oxford University Press, 1999.
- Heer**, Jeffrey, and Michael Bostock. "Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design." In *Proceedings of the Sigchi Conference on Human Factors in Computing Systems*, 203–12, 2010.

- Koponen**, Juuso, and Jonatan Hildén. *Data Visualization Handbook*. First. Finland: Aalto Art Books, 2019.
- Leborg**, Christian. *Visual Grammar*. Princeton Architectural Press, 2004.
- Spencer**, Scott. (Draft) Proposal to Scott Powers. "Proposal for Exploring Game Decisions Informed by Expectations of Joint Probability Distributions." February 14, 2019.
- Tufte**, Edward R. *The Visual Display of Quantitative Information*. Second. Graphics Press, 2001.
- . *Visual Explanations. Images and Quantities, Evidence and Narrative*. Graphics Press, 1997.
- Ware**, Colin. *Information Visualization: Perception for Design*. Fourth. Philadelphia: Elsevier, Inc, 2020.
- Wickham**, Hadley. "A Layered Grammar of Graphics." *Journal of Computational and Graphical Statistics* 19, no. 1 (January 2010): 3–28.
- Wilke**, C. *Fundamentals of Data Visualization: A Primer on Making Informative and Compelling Figures*. First edition. Sebastopol, CA: O'Reilly Media, 2019.
- Wilkinson**, Leland. *The Grammar of Graphics*. Second. Springer, 2005.