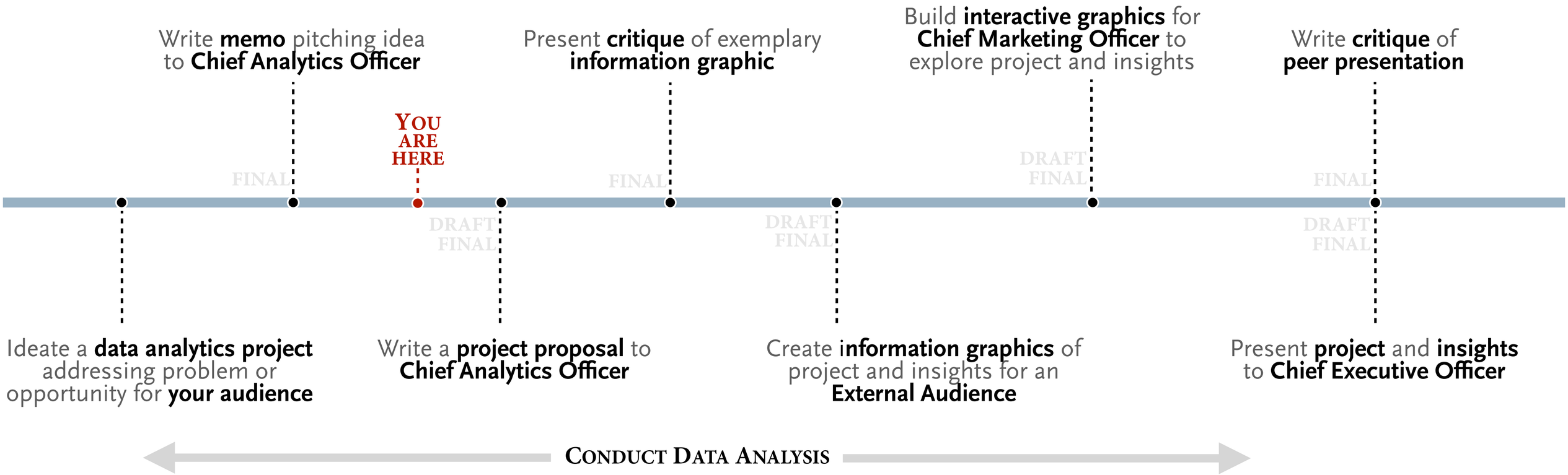
Storytelling with data

05 | visual design, data encodings, perceptual psychology

Scott Spencer | Columbia University

course overview | main course deliverables



Why show data graphically?

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

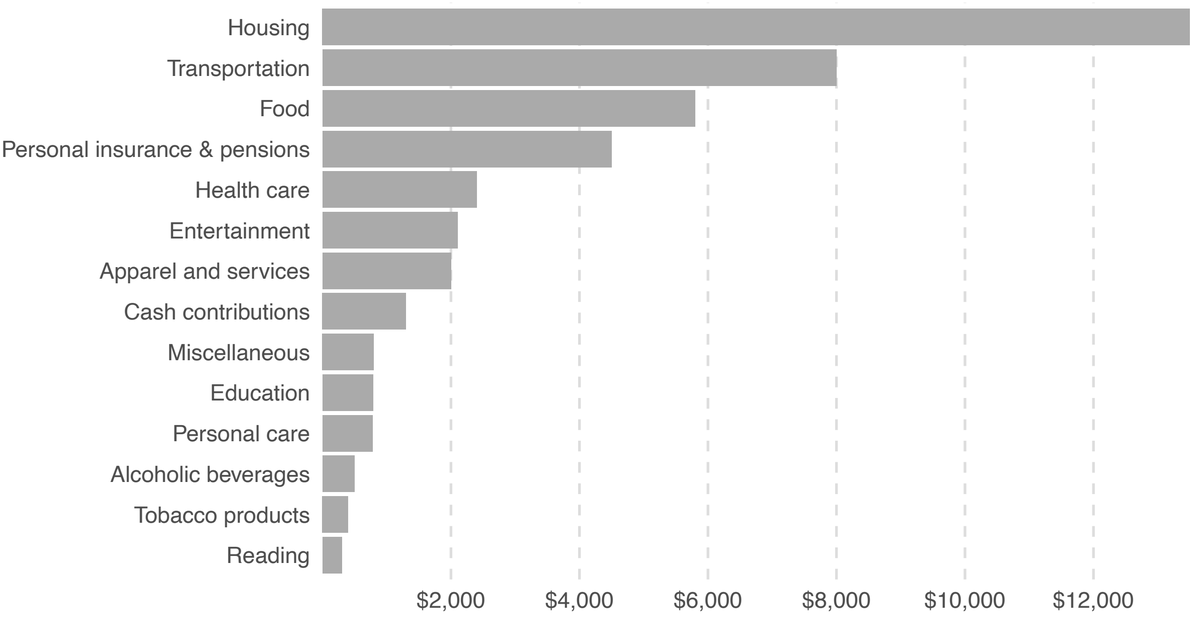


Fig. 3. Major categories of expenditures, descending dollar value, 2002 U.S. Consumer Expenditure Survey

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, 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*

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

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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	p-val
Dataset 1				
(Intercept)	3.000	1.125	2.667	0.026
x	0.500	0.118	4.241	0.002
Dataset 2				
(Intercept)	3.001	1.125	2.667	0.026
x	0.500	0.118	4.239	0.002
Dataset 3				
(Intercept)	3.002	1.124	2.670	0.026
x	0.500	0.118	4.239	0.002
Dataset 4				
(Intercept)	3.002	1.124	2.671	0.026
x	0.500	0.118	4.243	0.002

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
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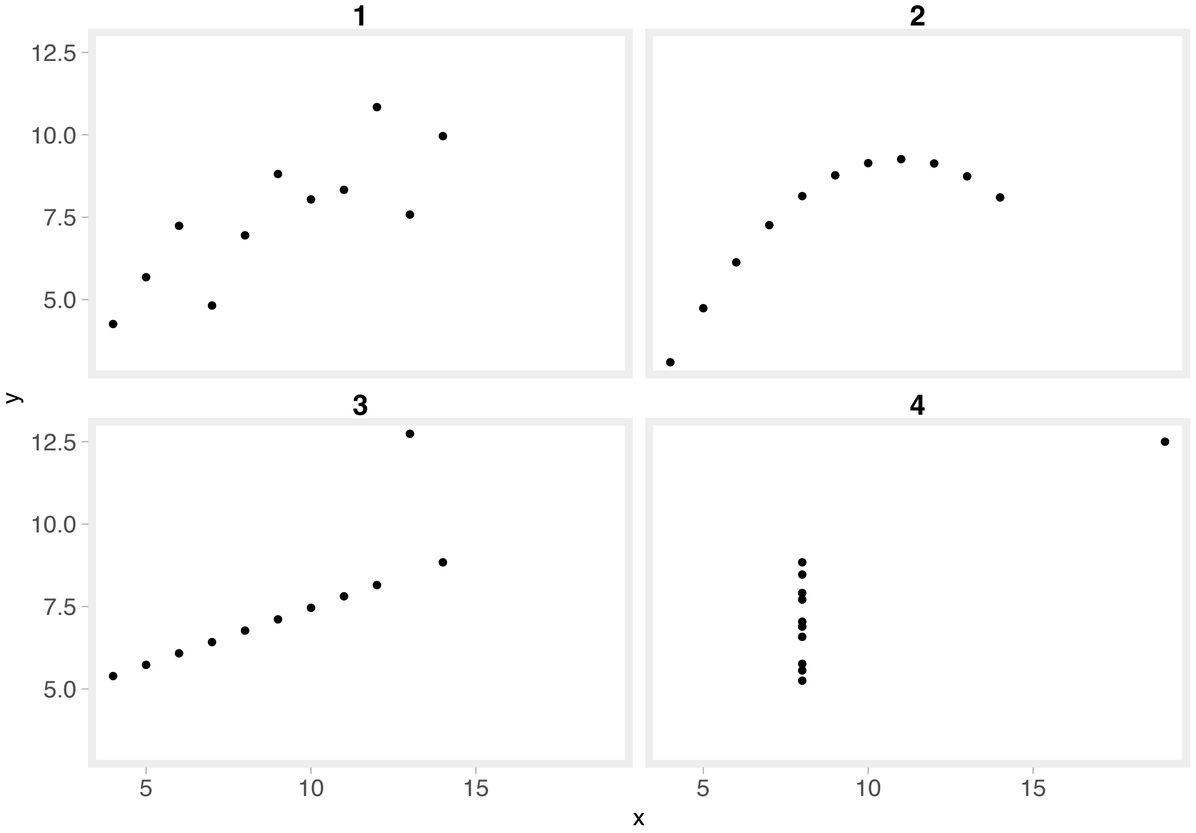
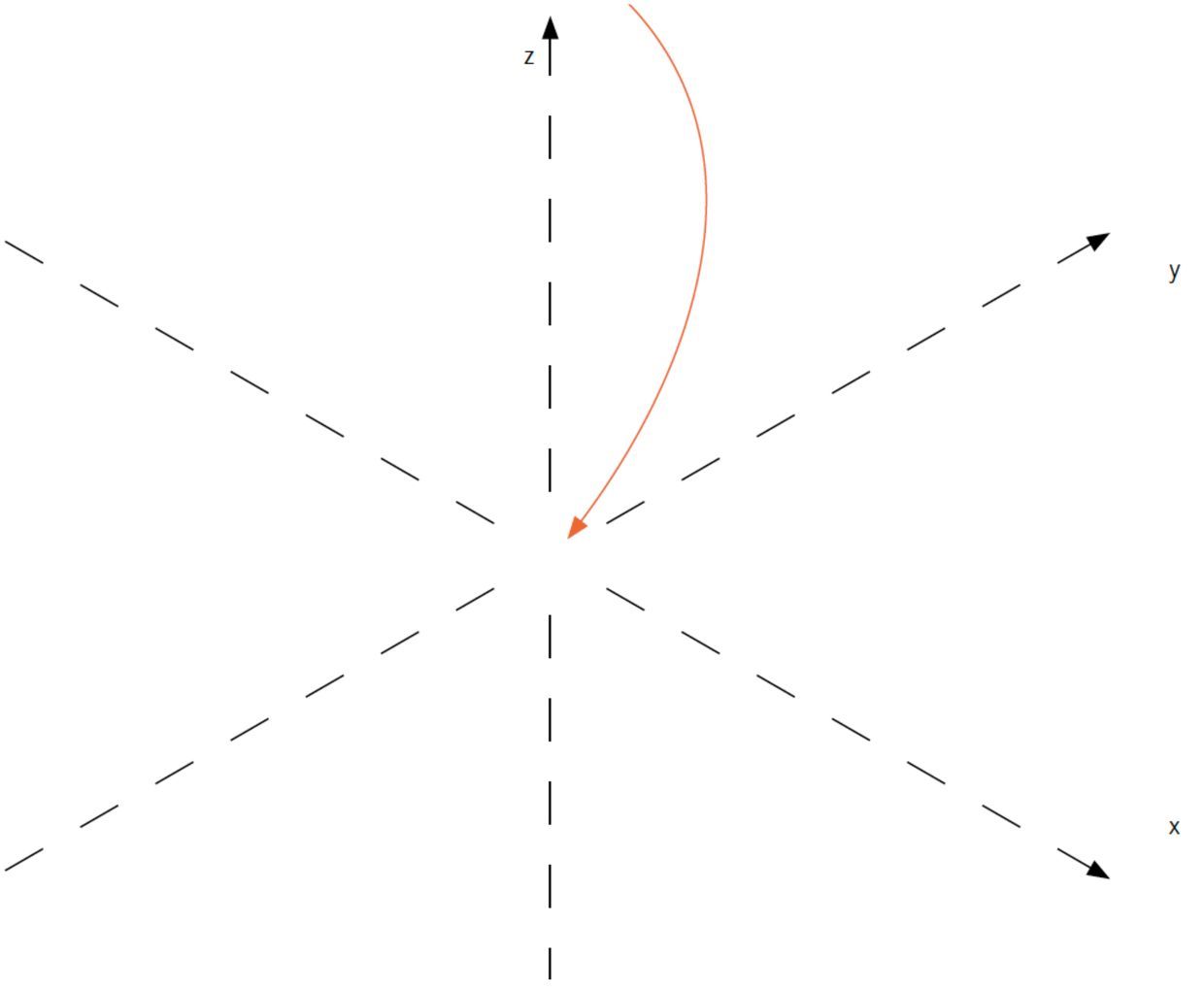
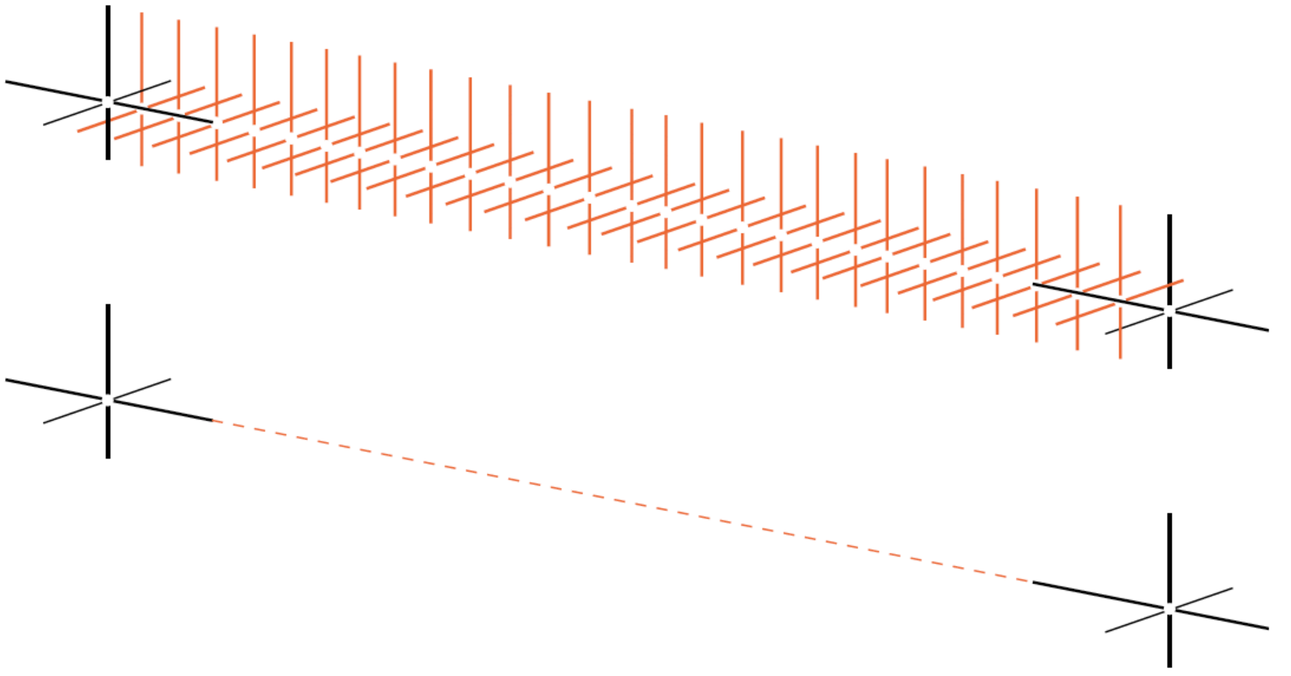
4	4.26	4	3.10	4	5.39	19	12.50
12	10.84	12	9.13	12	8.15	8	5.56
7	4.82	7	7.26	7	6.42	8	7.91
5	5.68	5	4.74	5	5.73	8	6.89

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

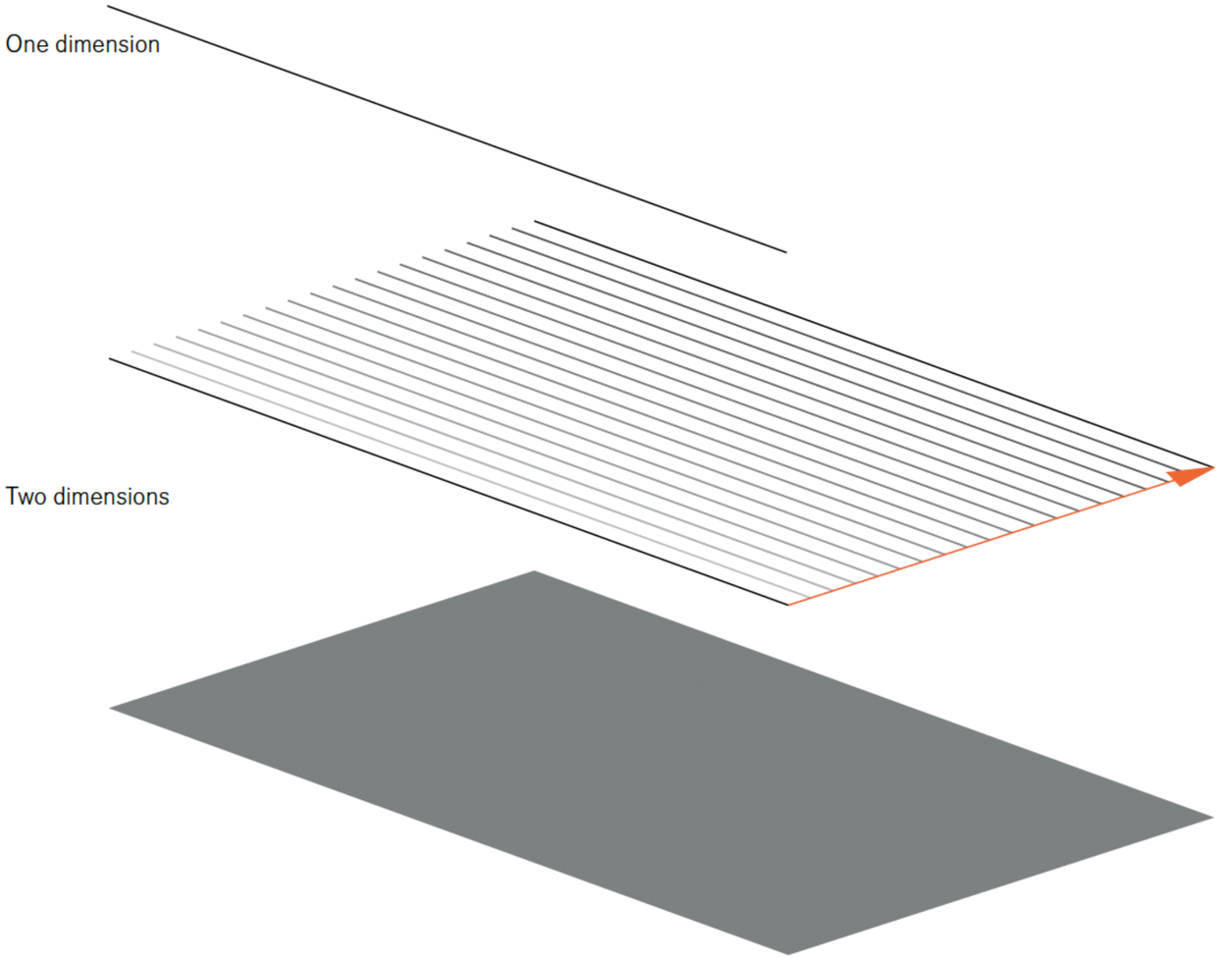


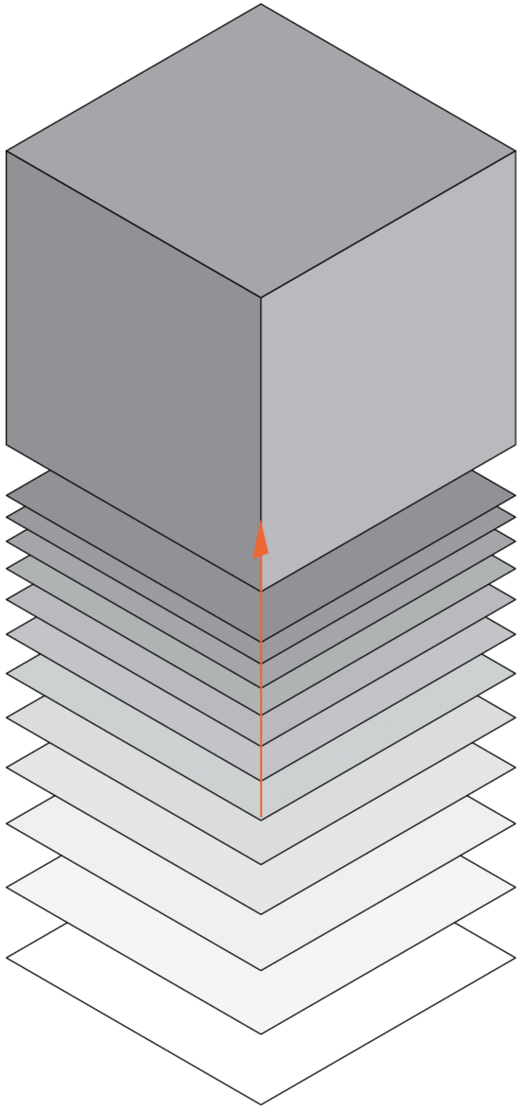
graphic design concepts


z
y
x



data encodings, geometry of graphical elements — surface





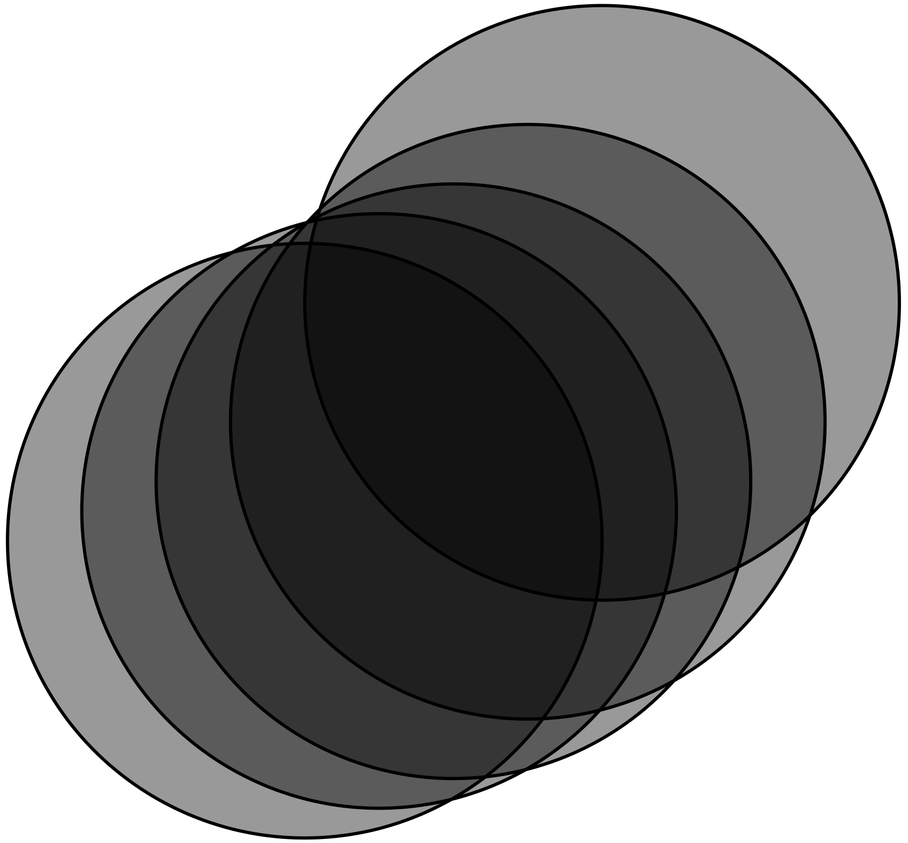
data encodings, layering — order of elements determines position towards reader and when overlapping, occlude

```
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

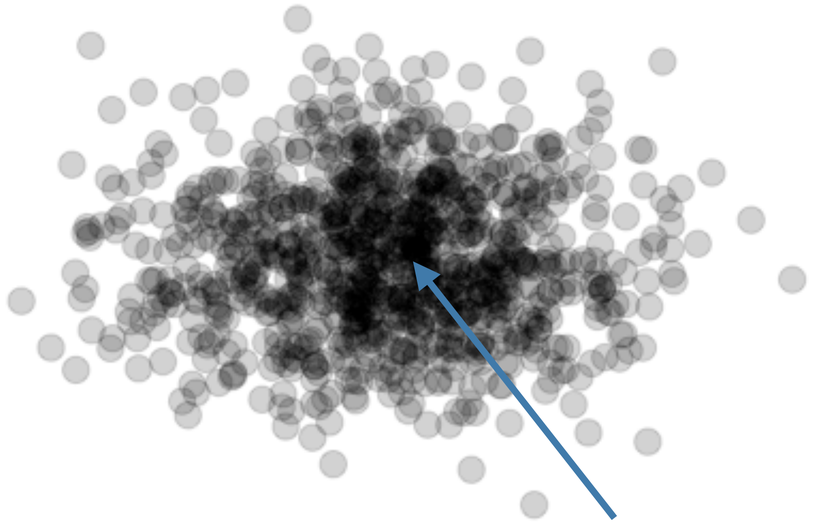
```
ggplot() +
  theme_void() +
  coord_equal() +
  ggforce::geom_circle(
    mapping = aes(
      x0 = seq(from = 0, to = 1, length.out = 5),
      y0 = c(0, .1, .2, .4, .8),
      r = 1),
    fill = "#000000",
    alpha = 0.4)
```



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

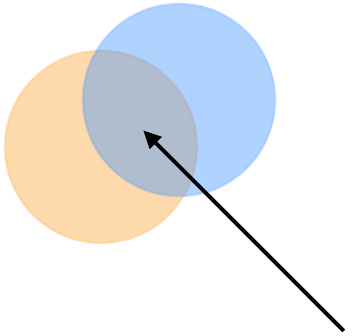
```
x <- rnorm(1000)
y <- rnorm(1000)

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)
```



dense areas of data are darker

```
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)
```

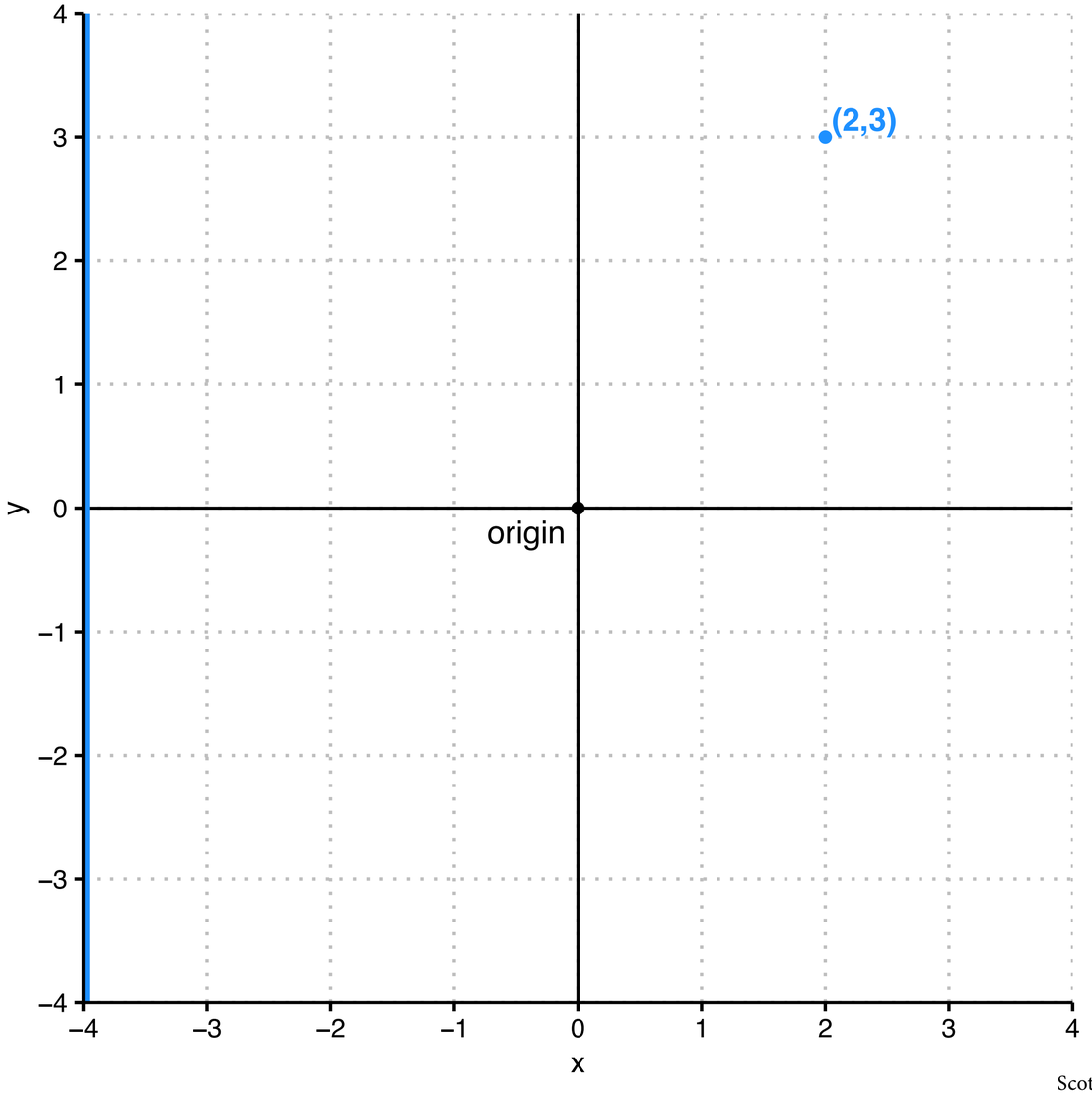


I didn't encode data with *this* color!?

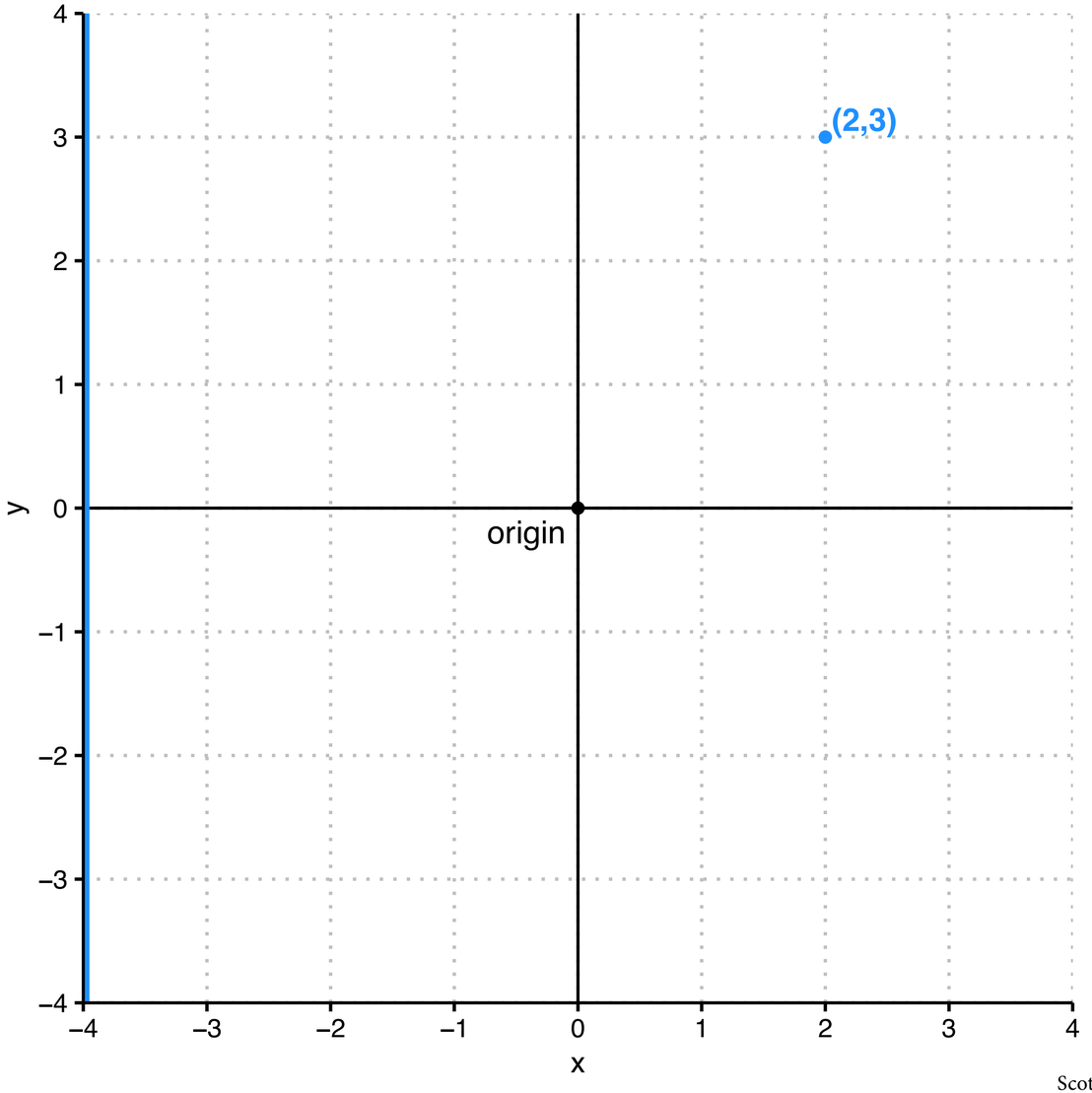
graphs — coordinate systems and scales

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

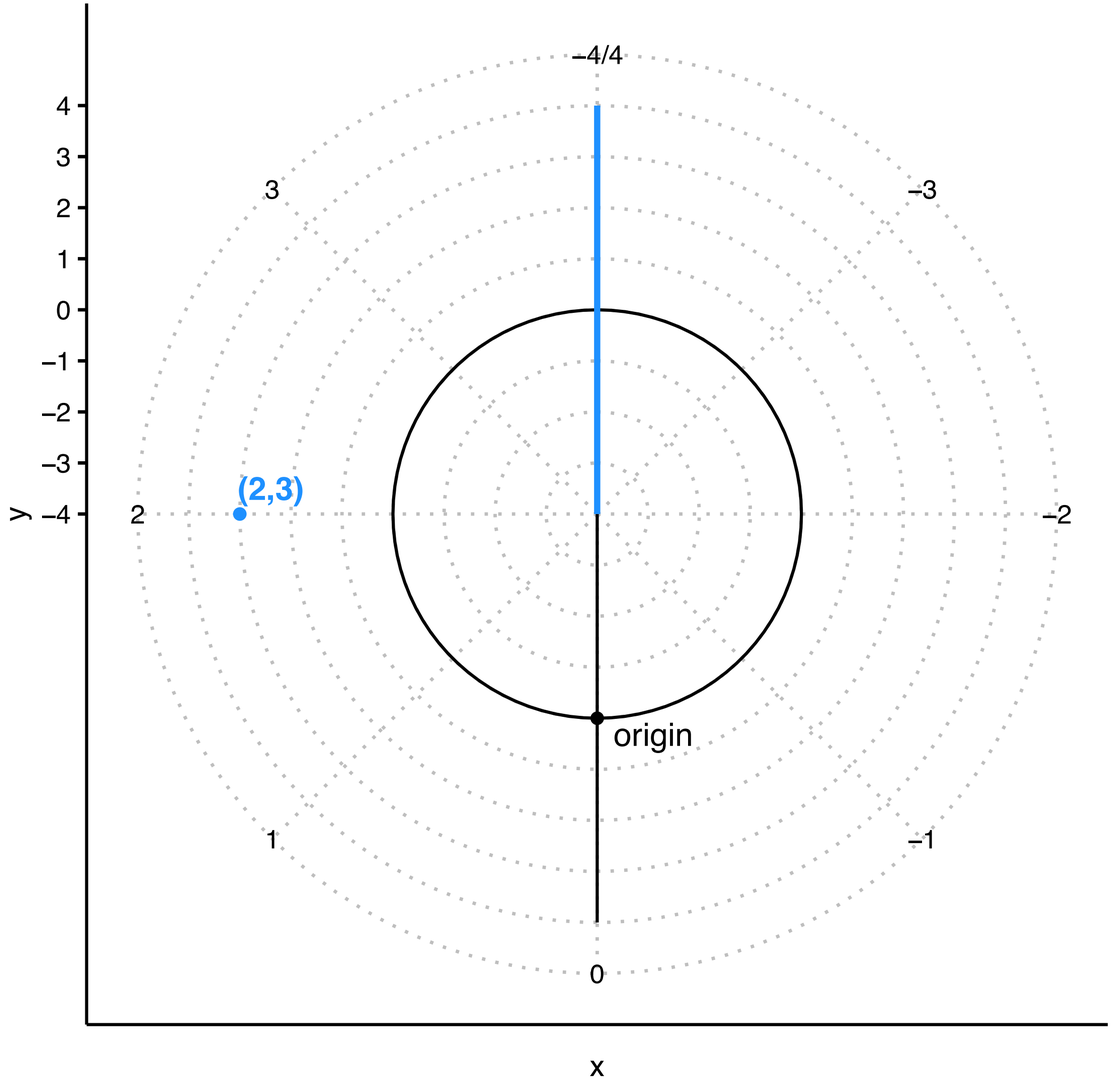
cartesian coordinates



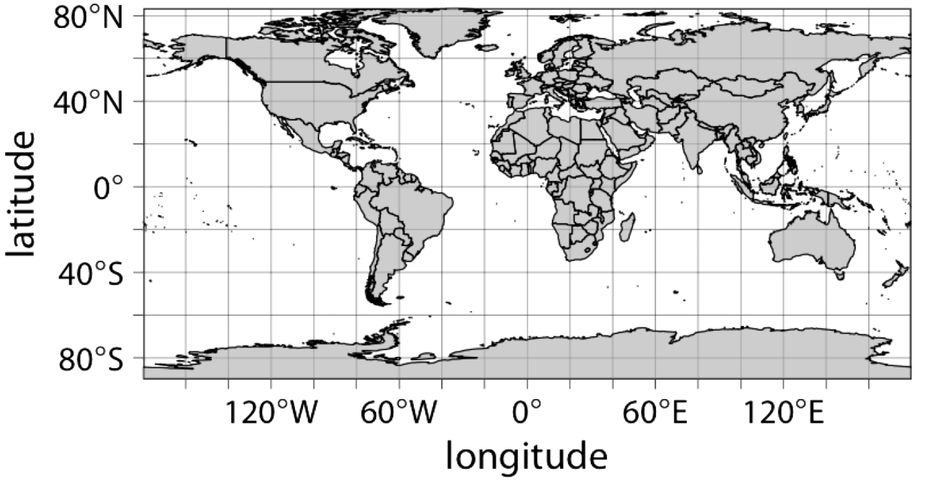
cartesian coordinates



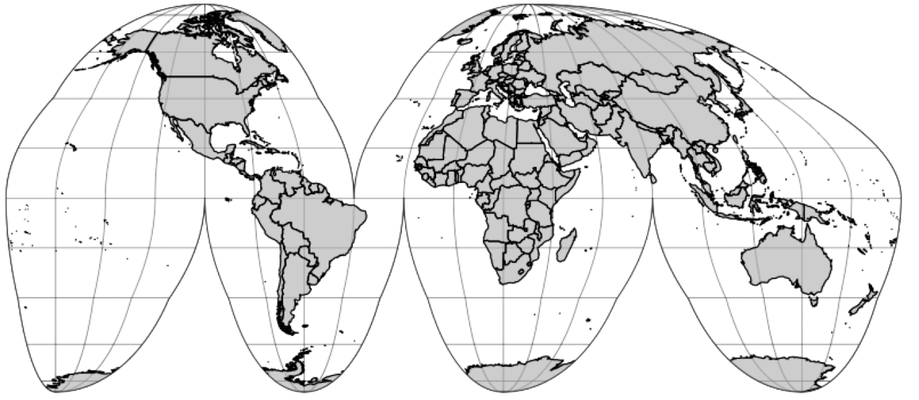
polar coordinates



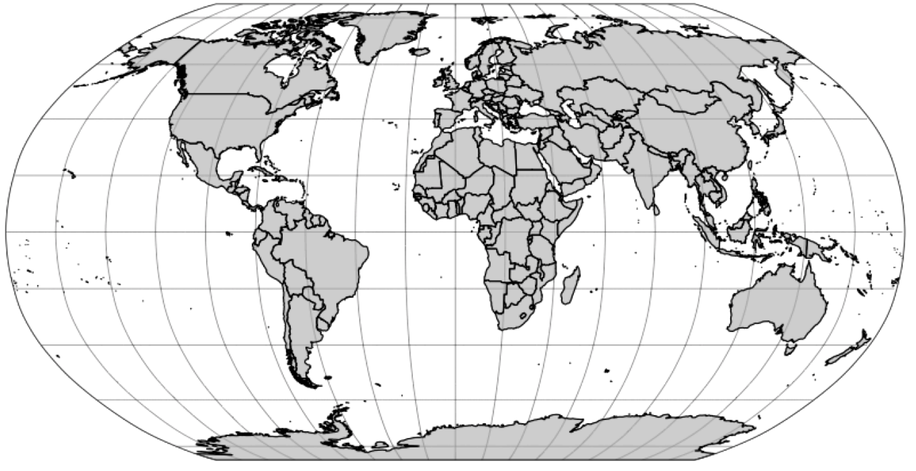
Cartesian longitude and latitude



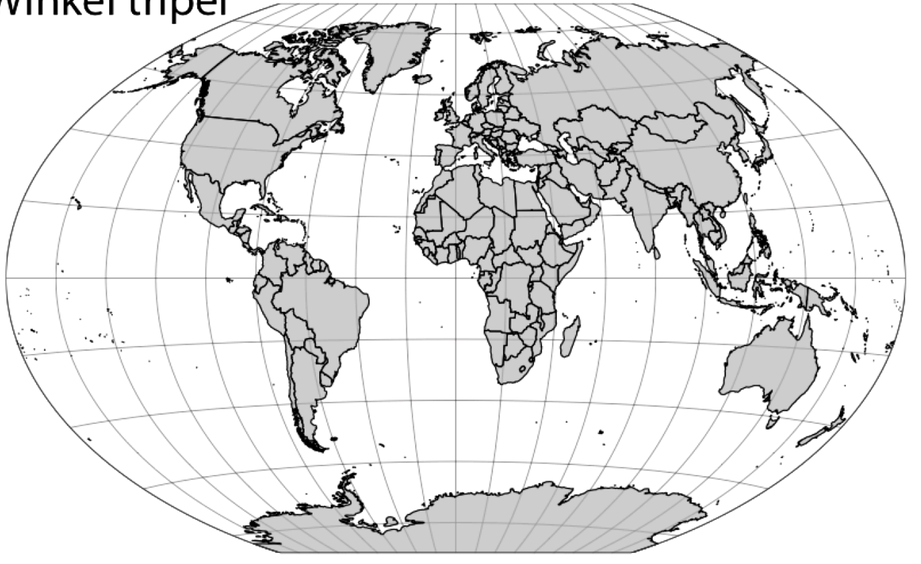
Interrupted Goode homolosine



Robinson

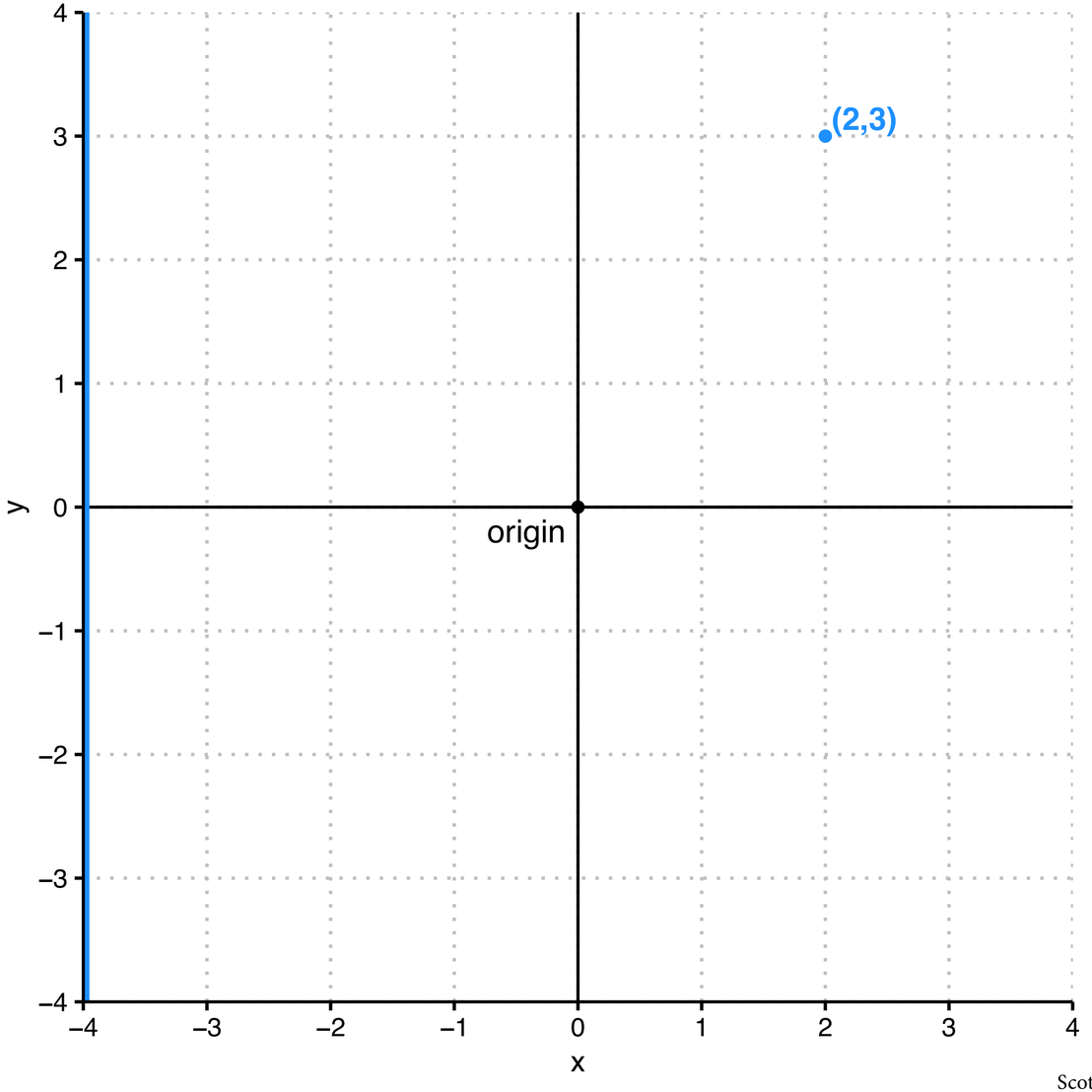


Winkel tripel

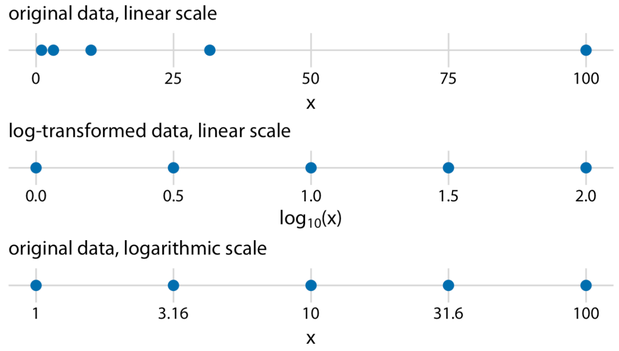


coordinates and scales, as with choosing coordinates, we can *transform* *scales for data or axes* for better understanding

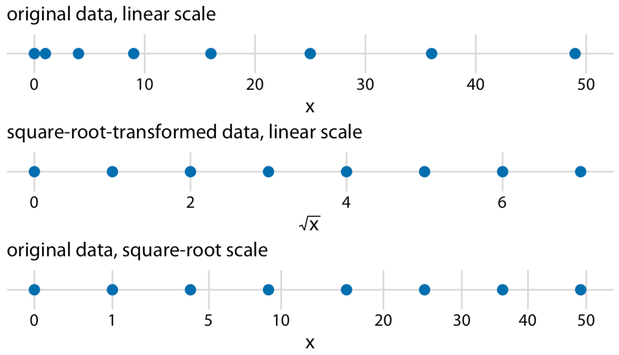
linear *scales* on cartesian coordinates



example — *log transforms*

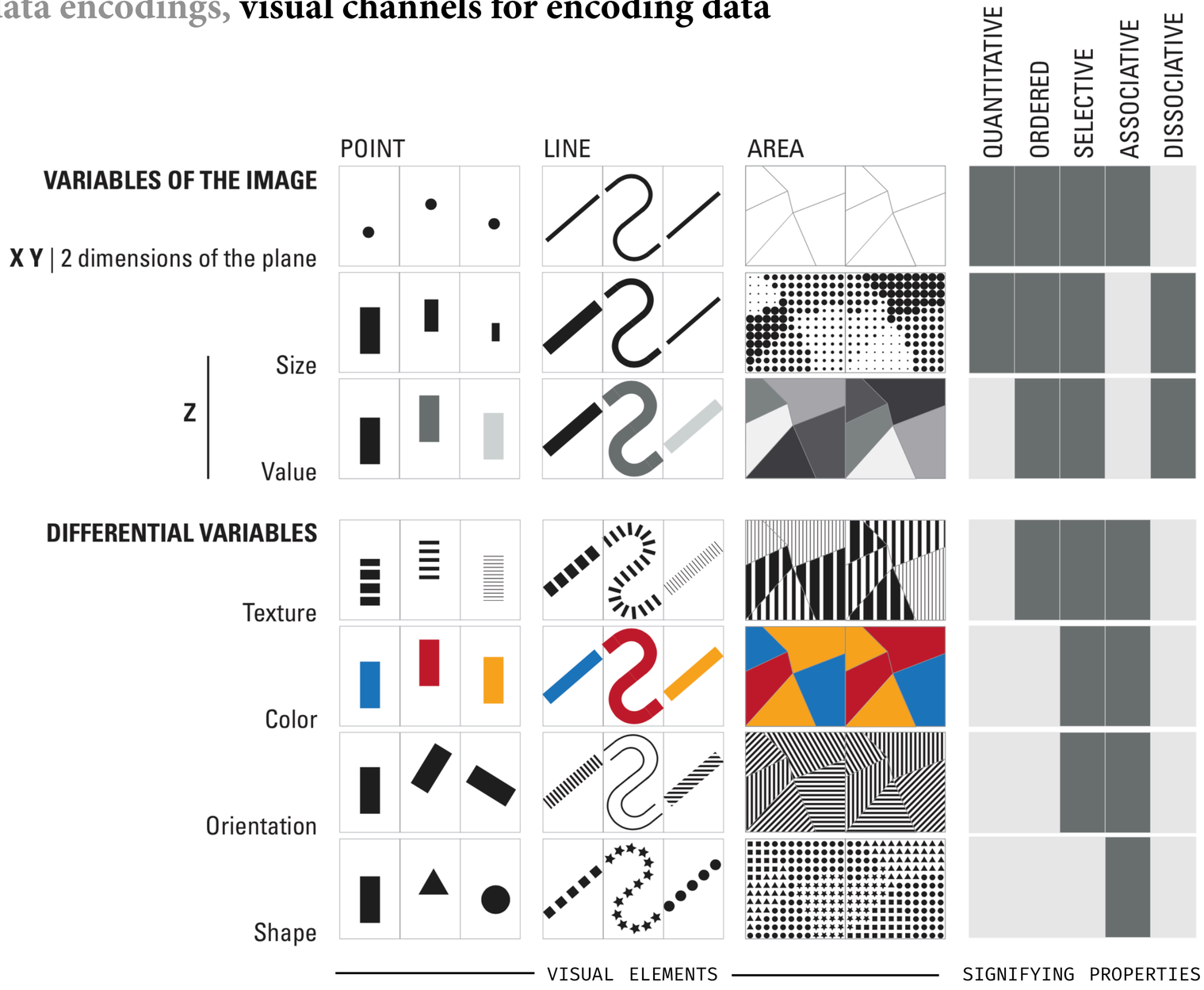


example — *square-root transforms*



data encodings for visual comparison

data encodings, visual channels for encoding data



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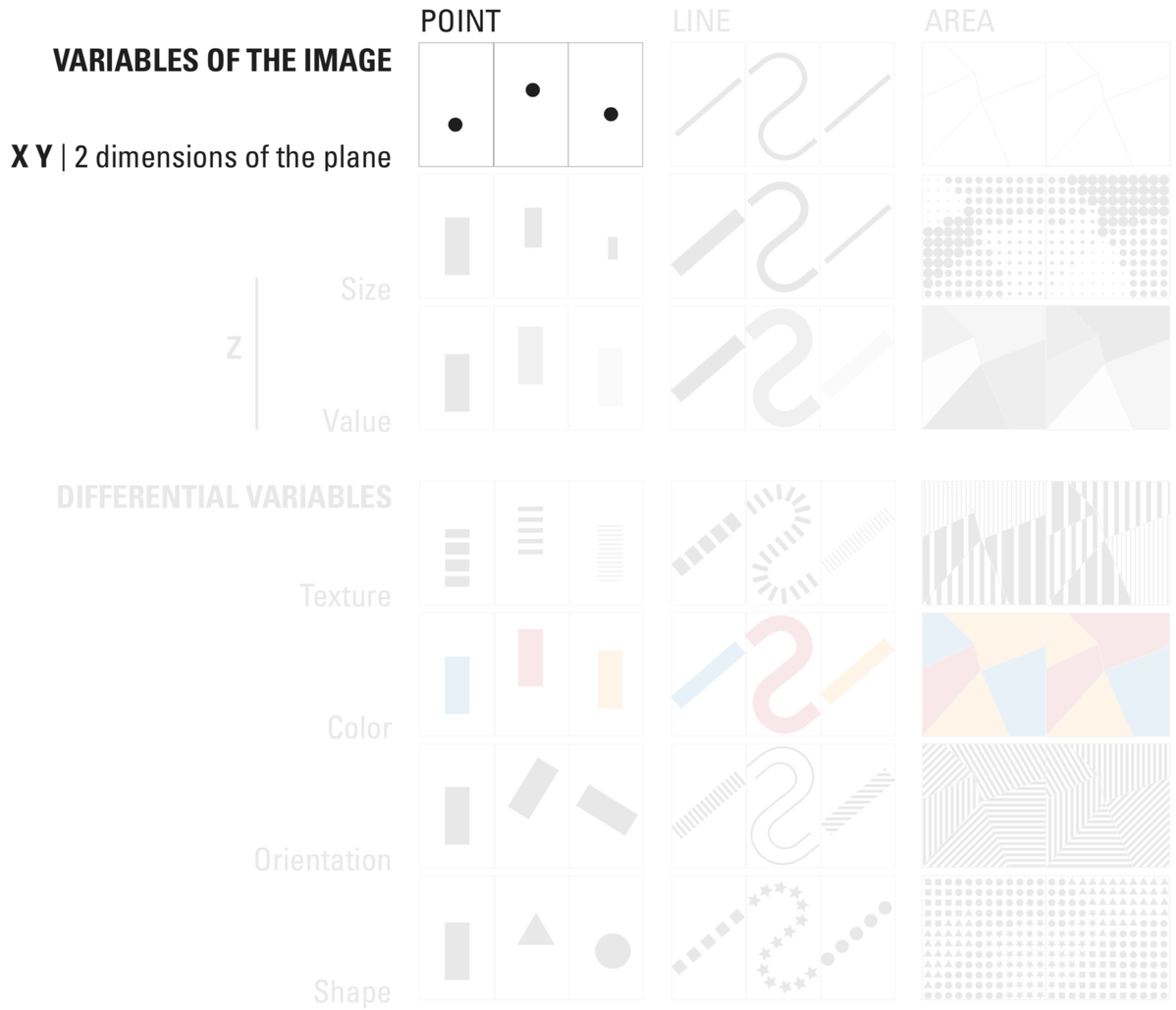
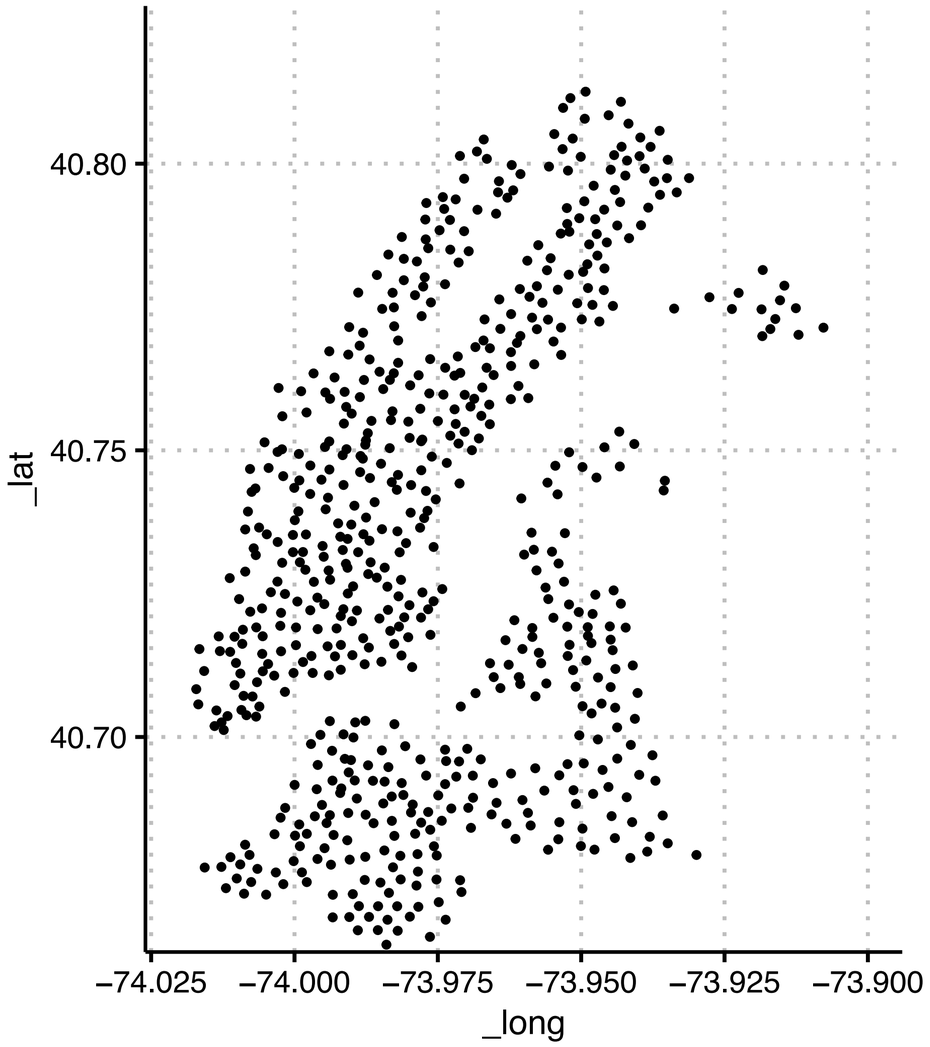


Citi Bike example — *exploratory data analysis*



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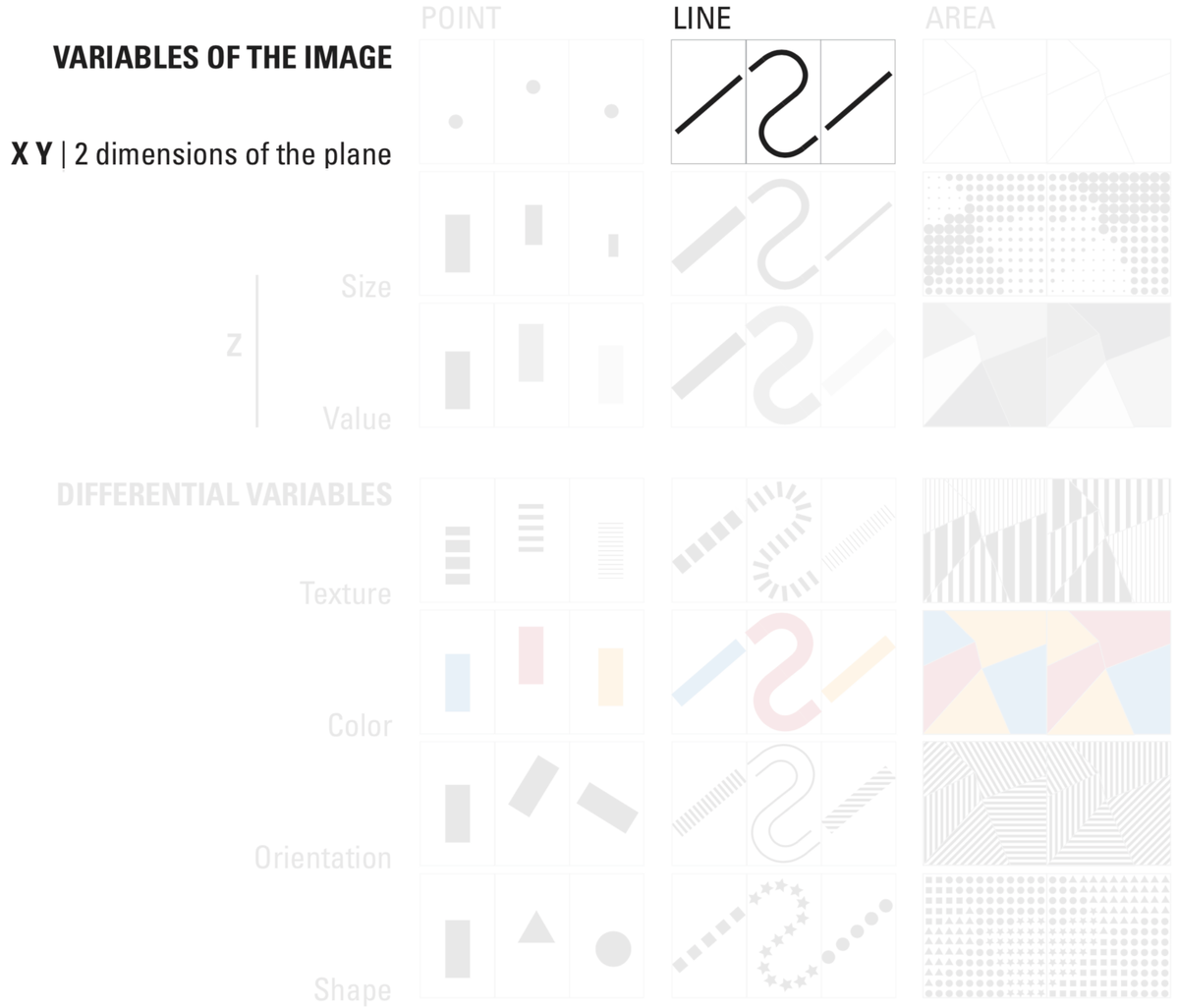
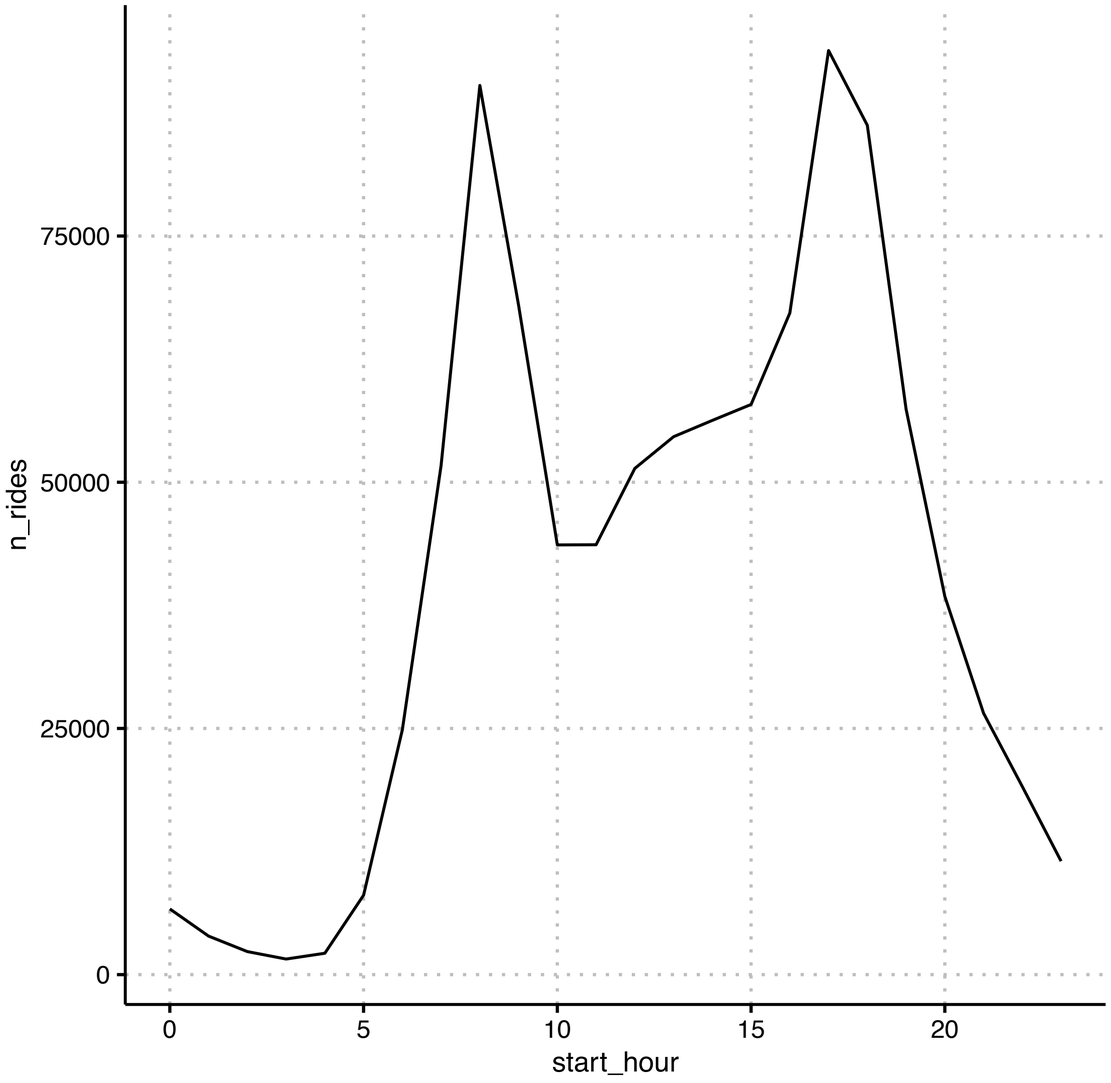


Citi Bike example — *exploratory data analysis*



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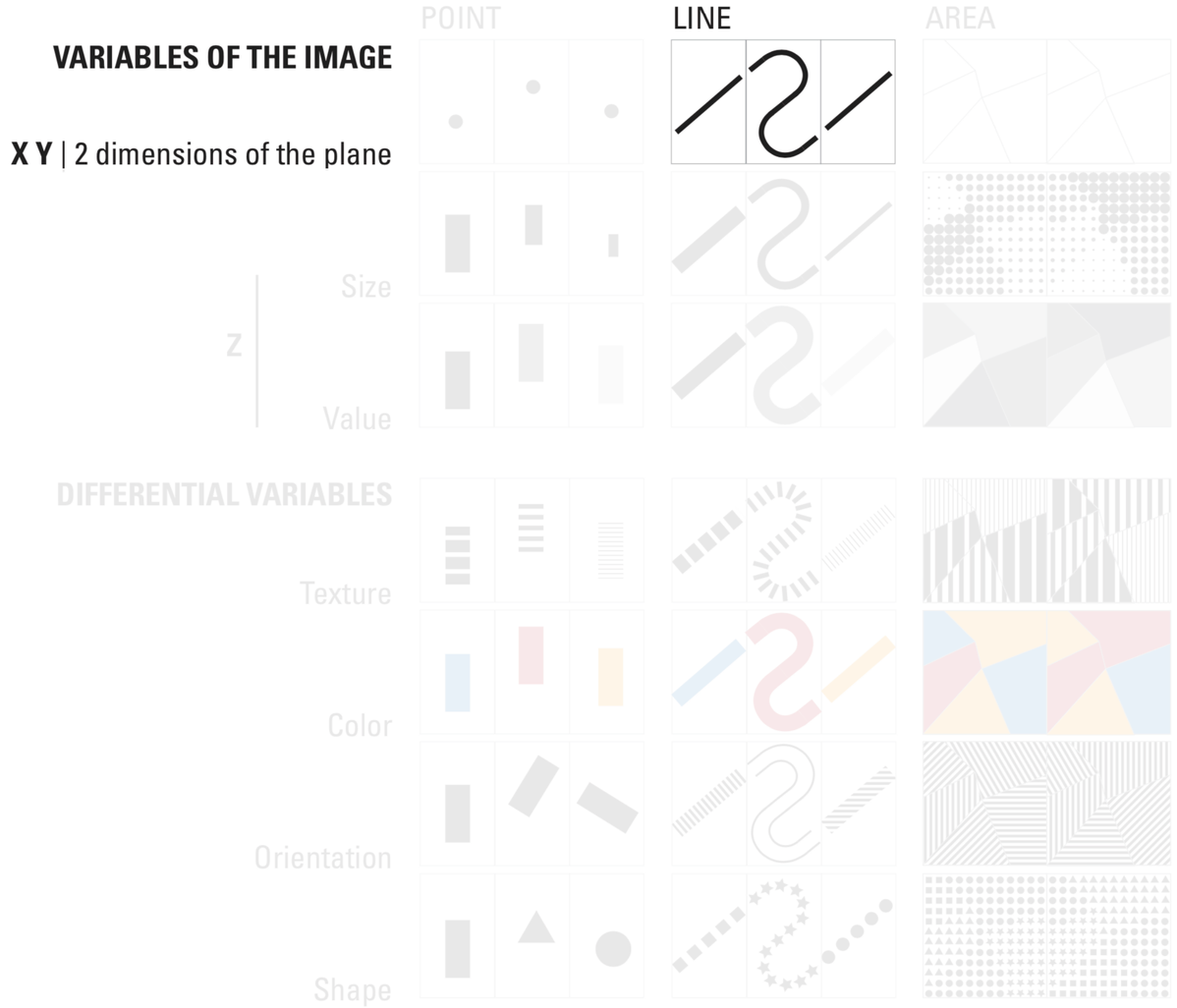

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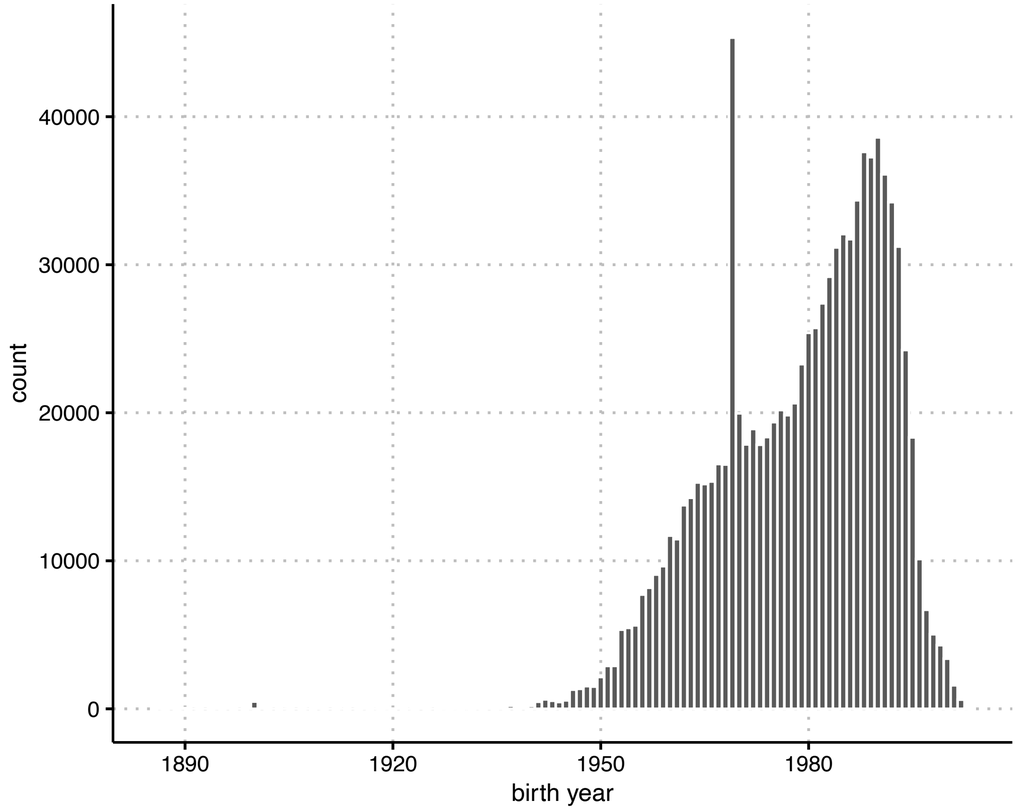

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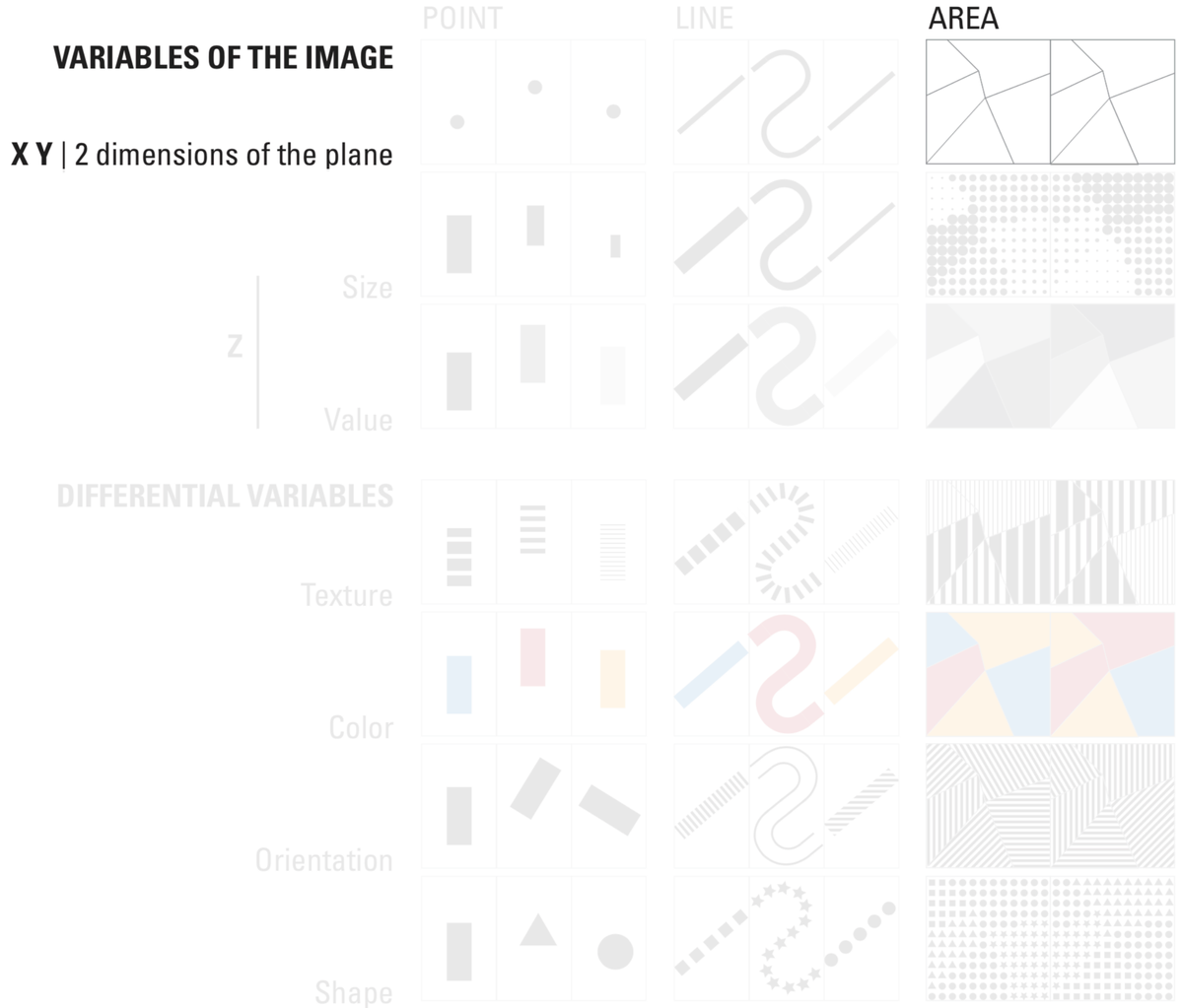

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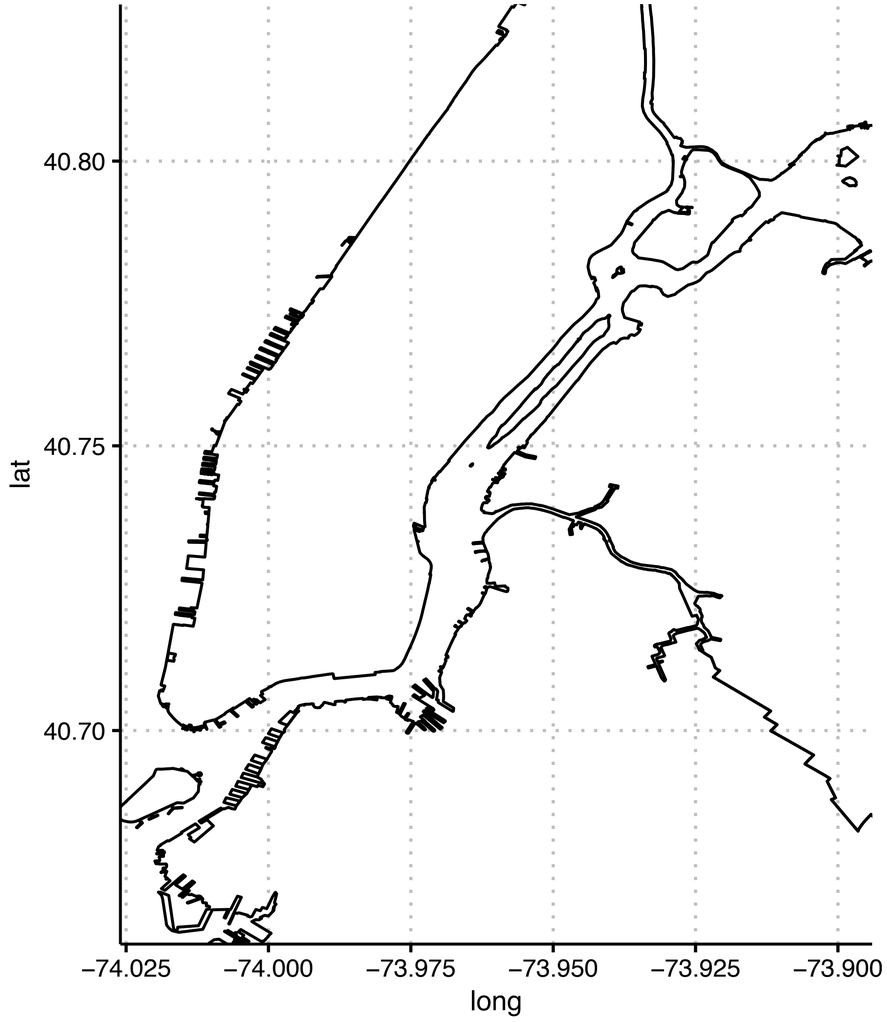

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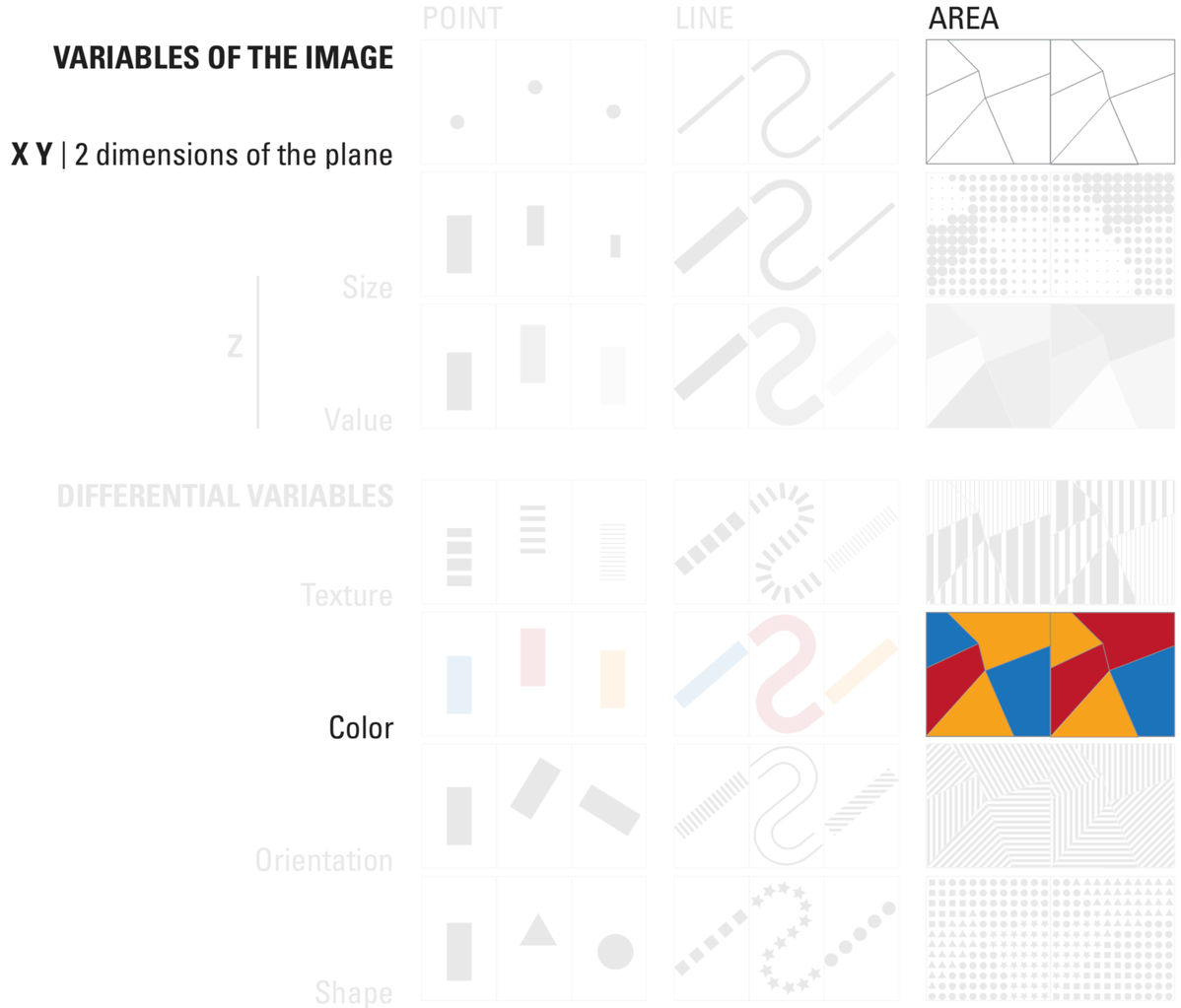

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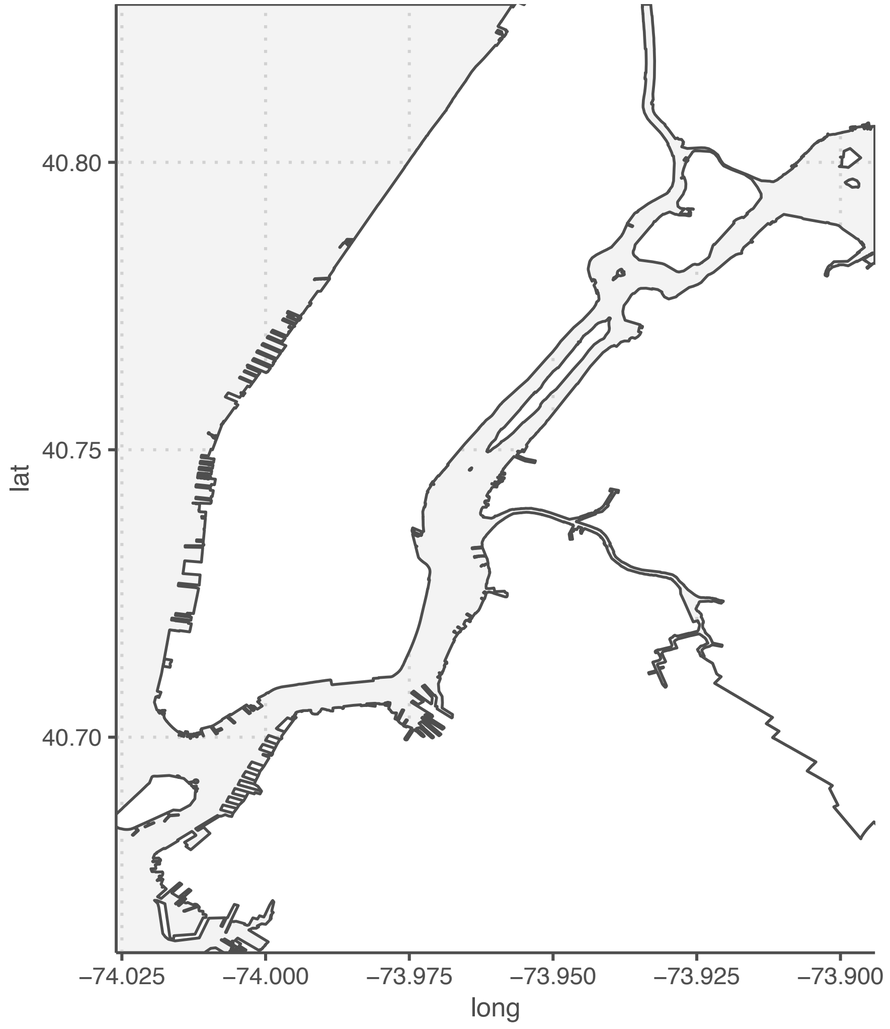

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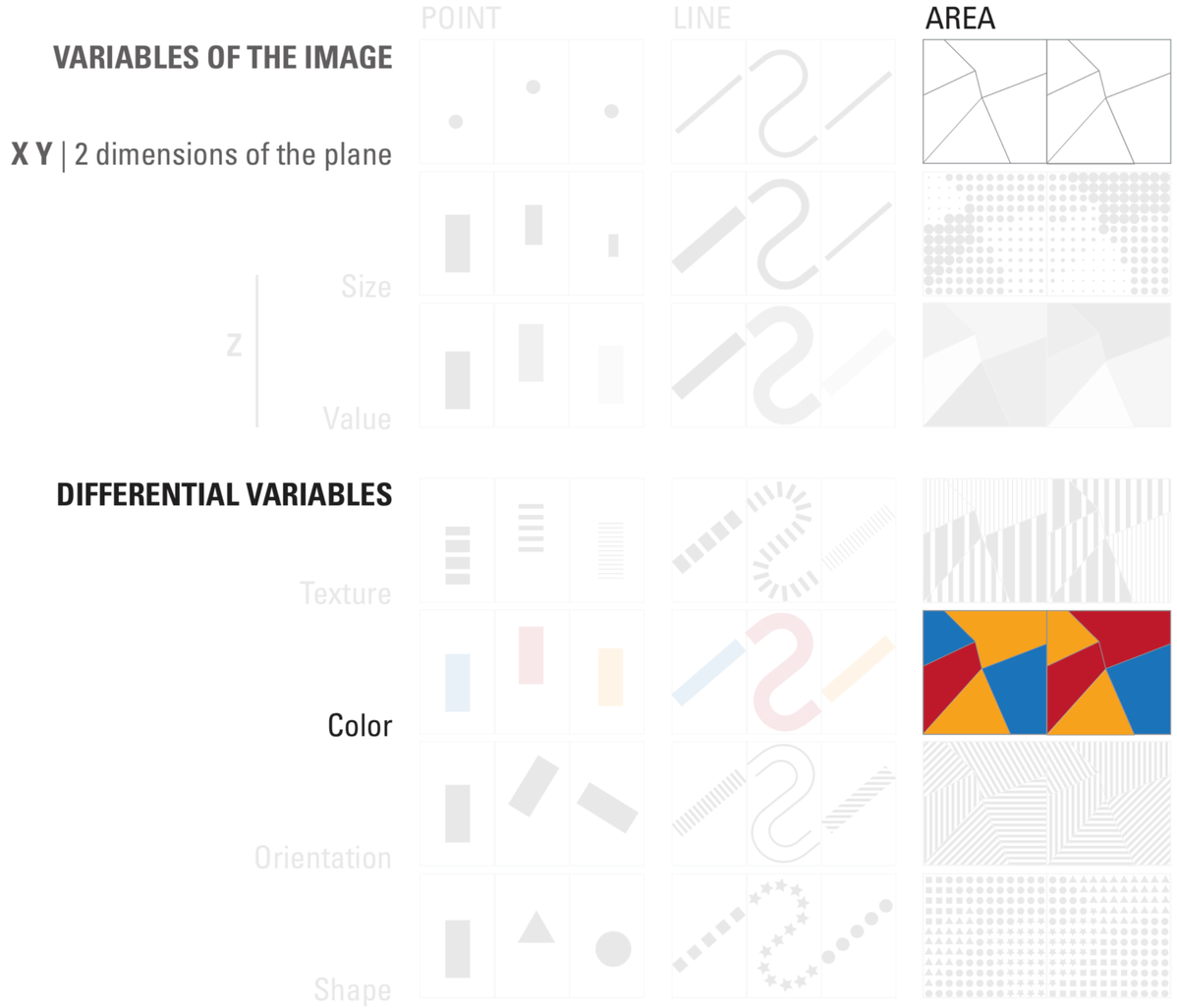

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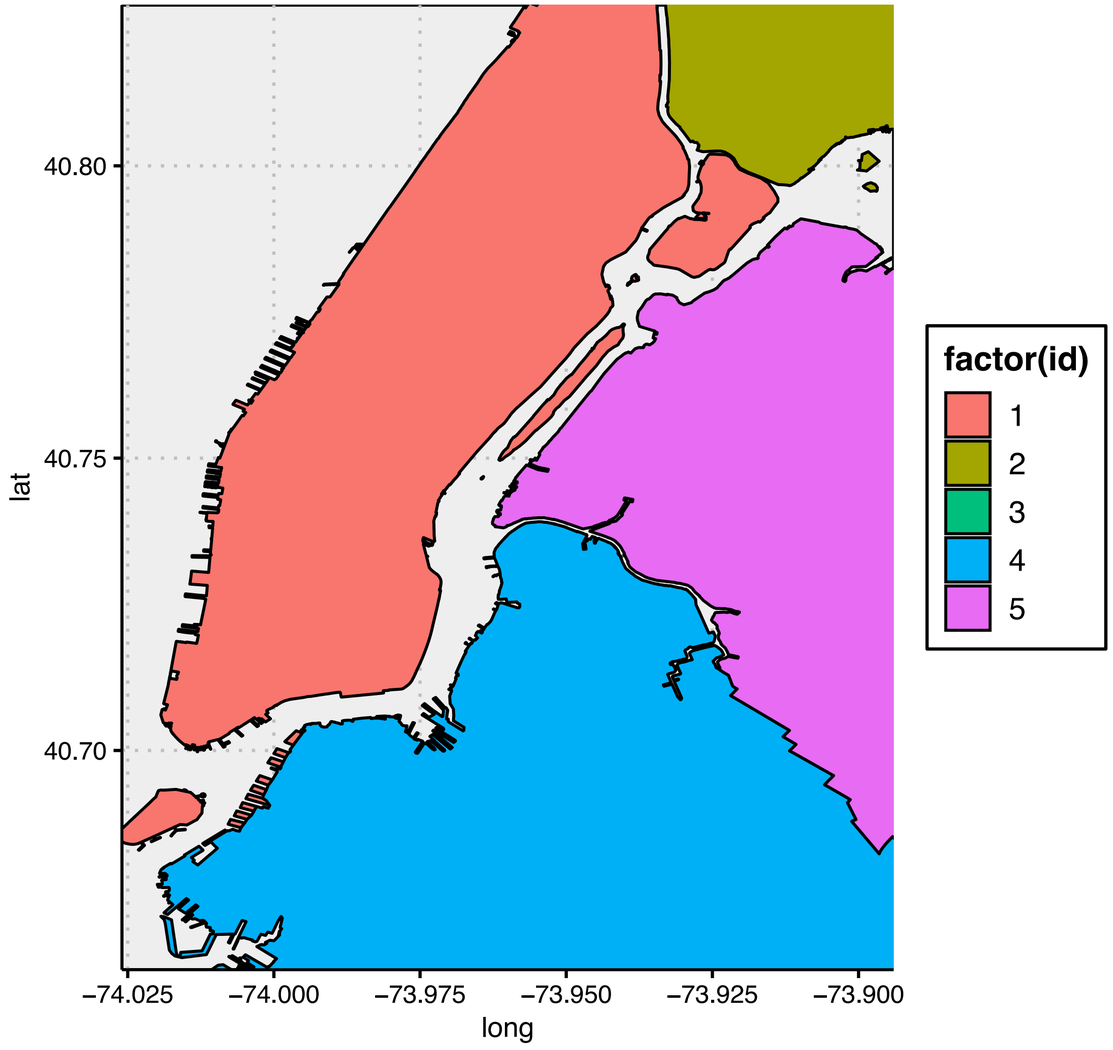

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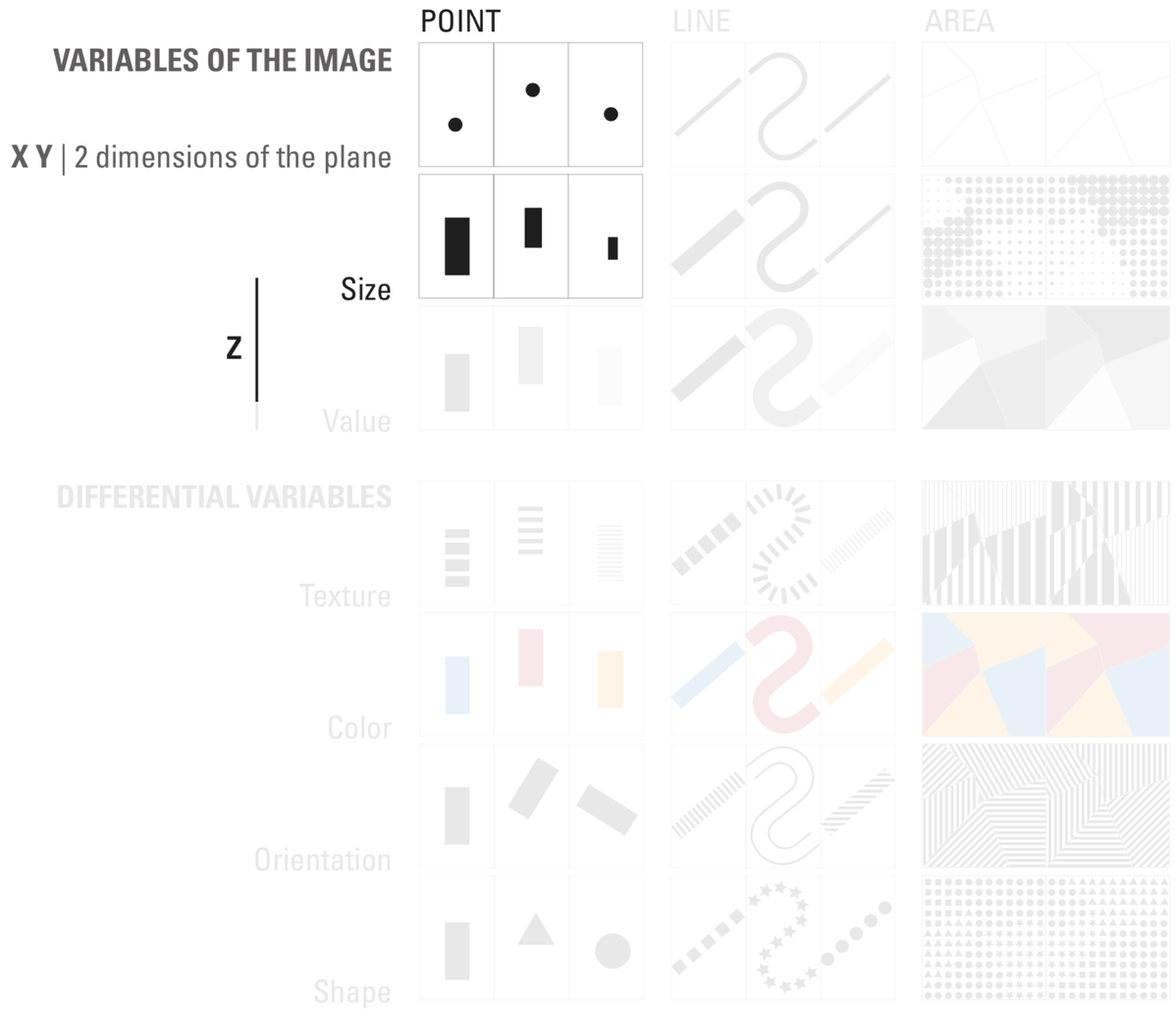

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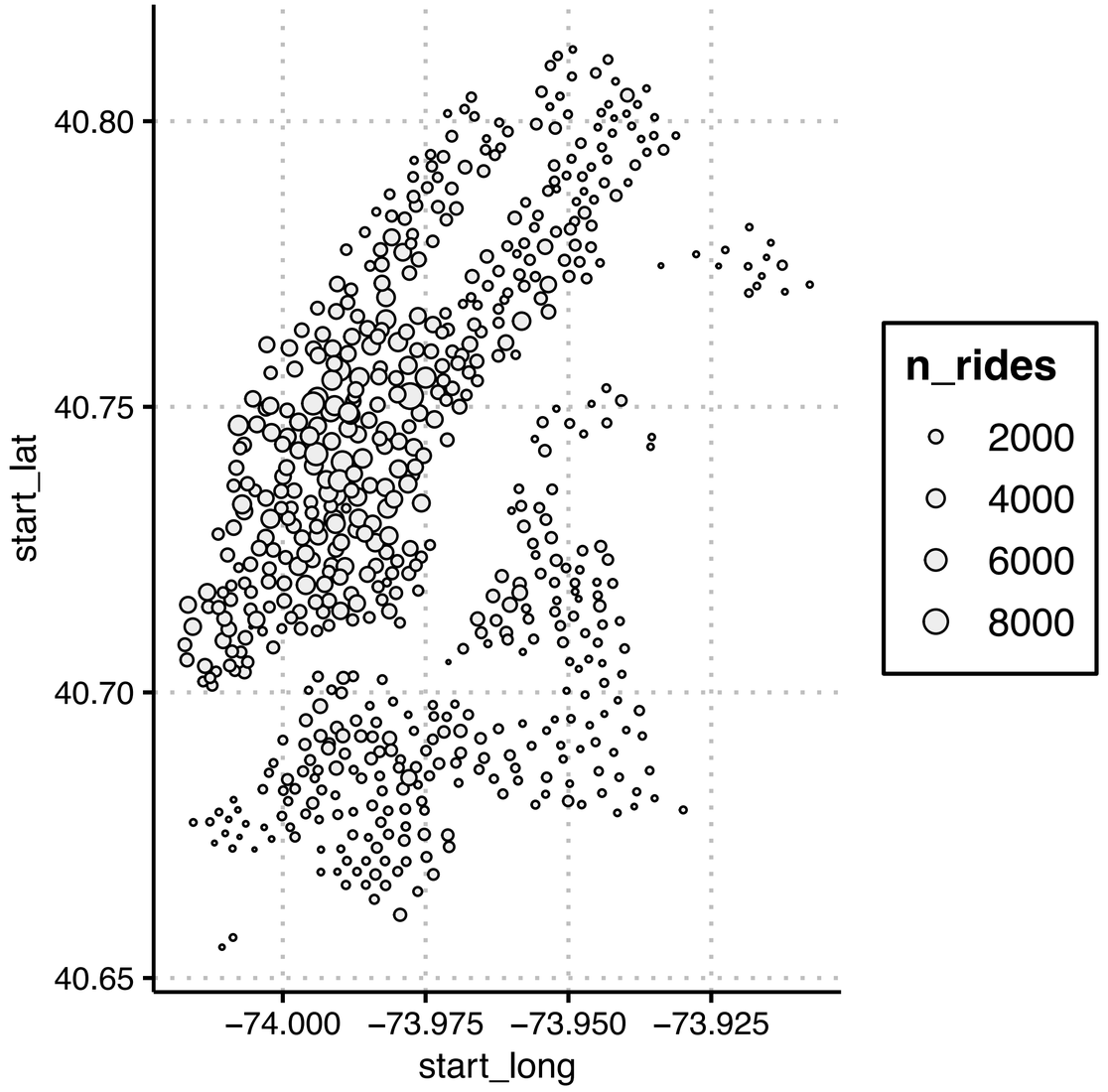

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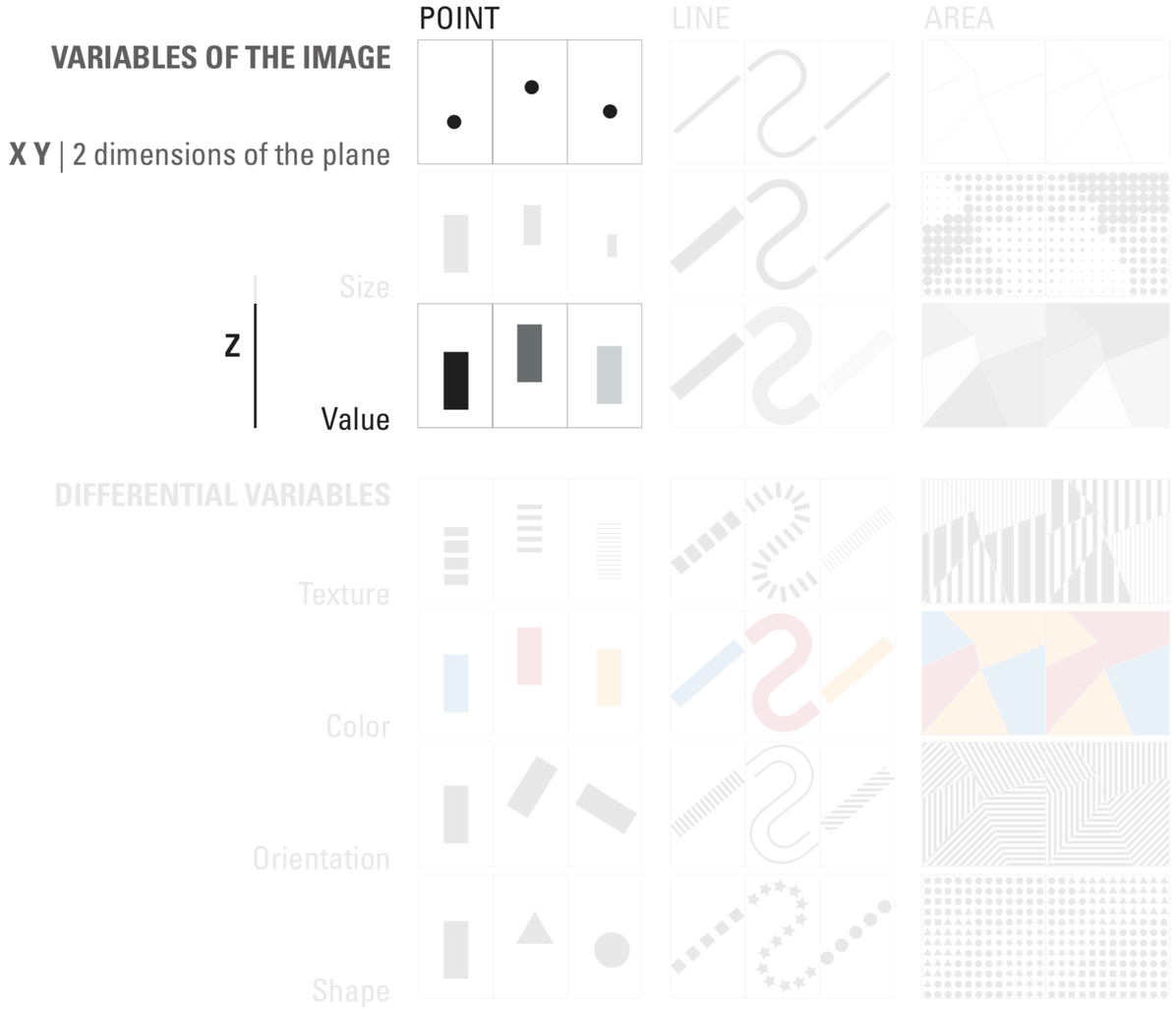

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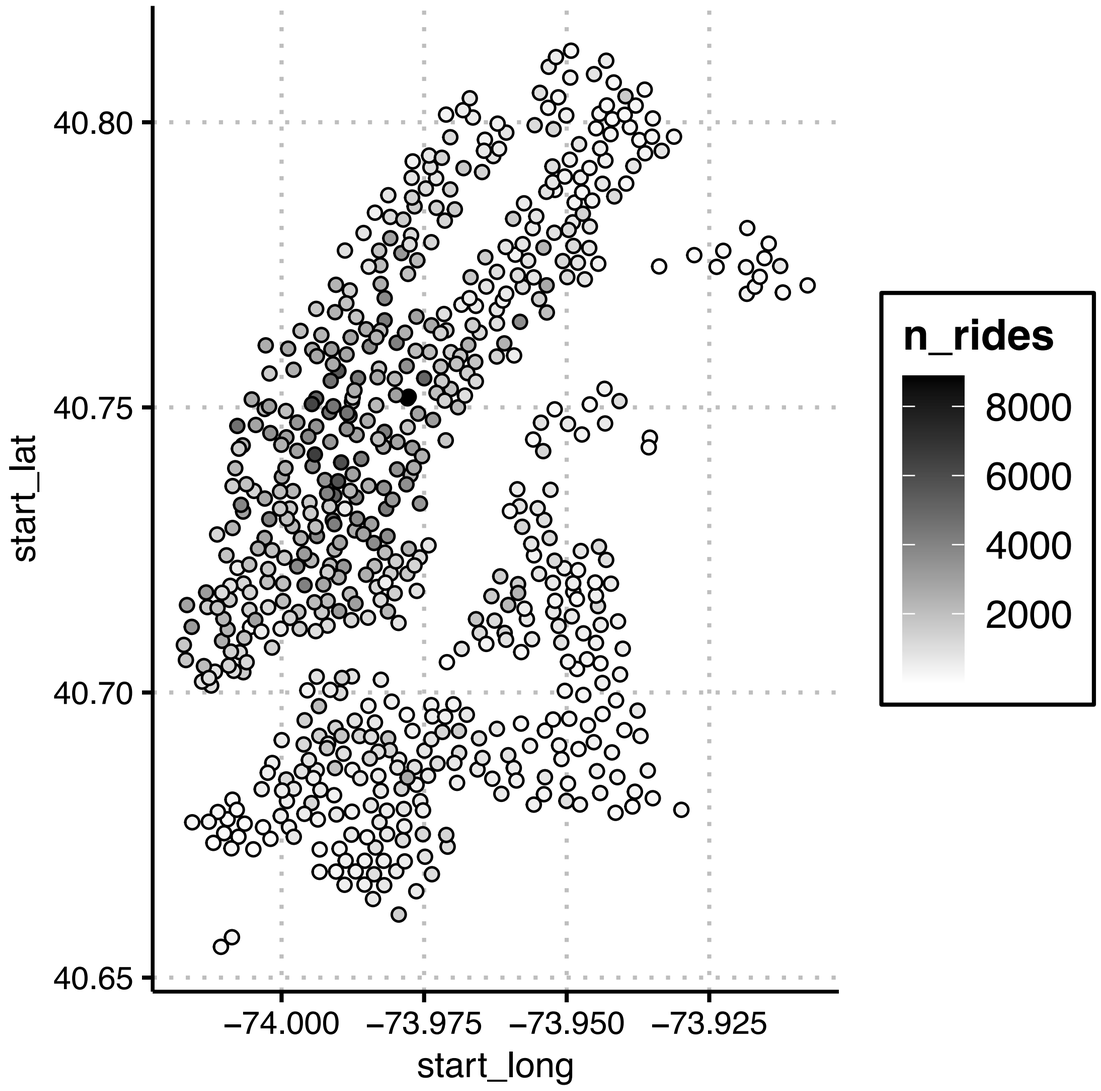

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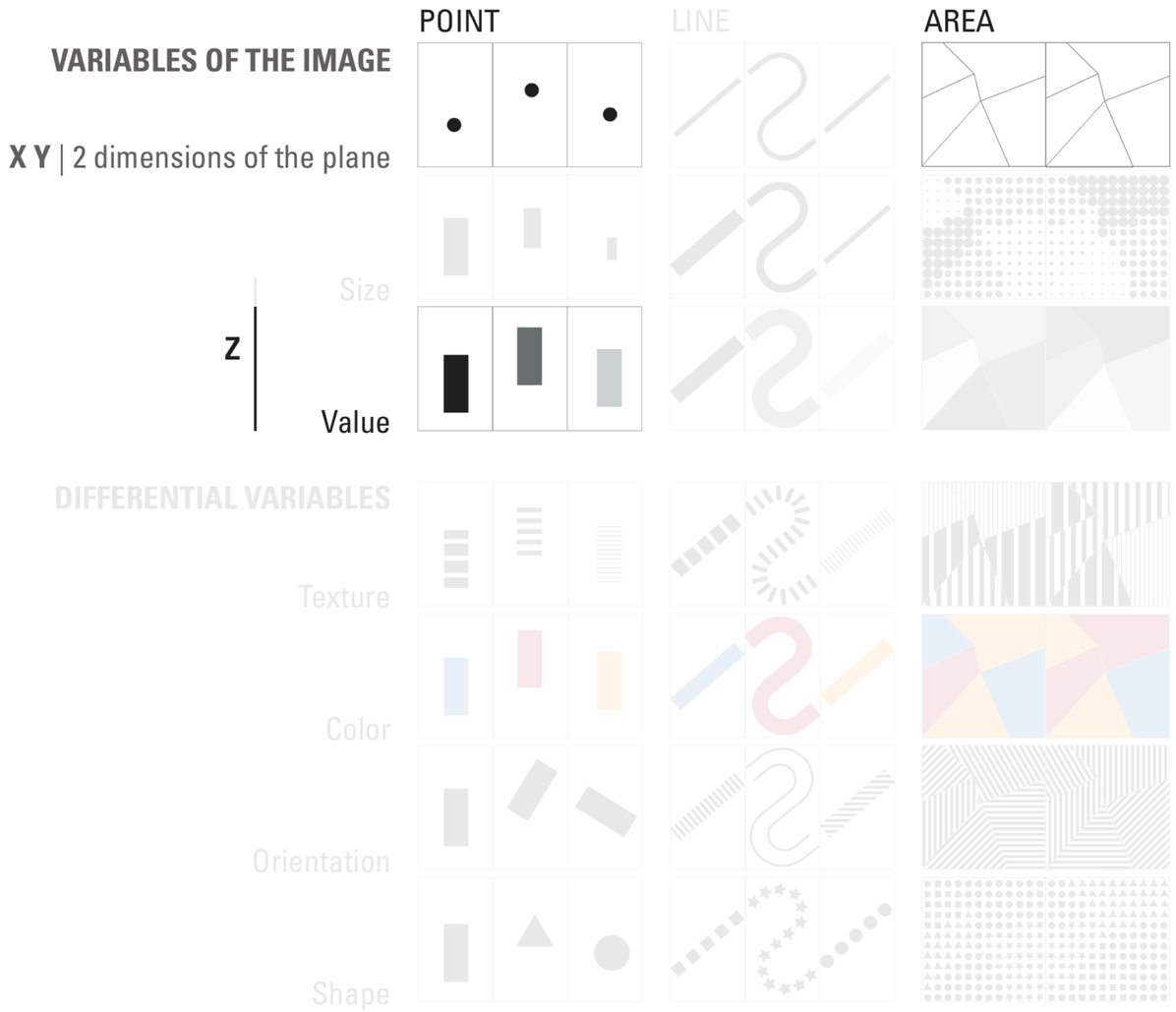

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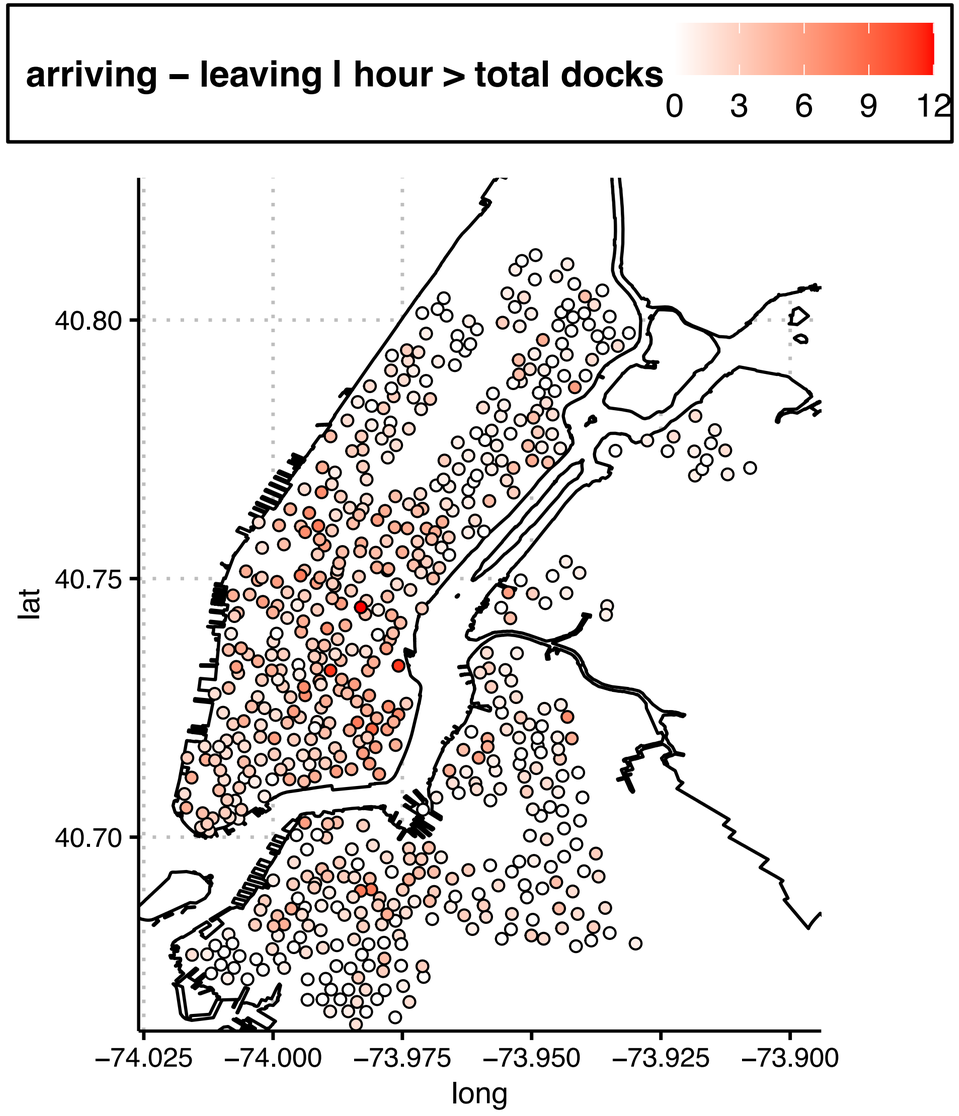

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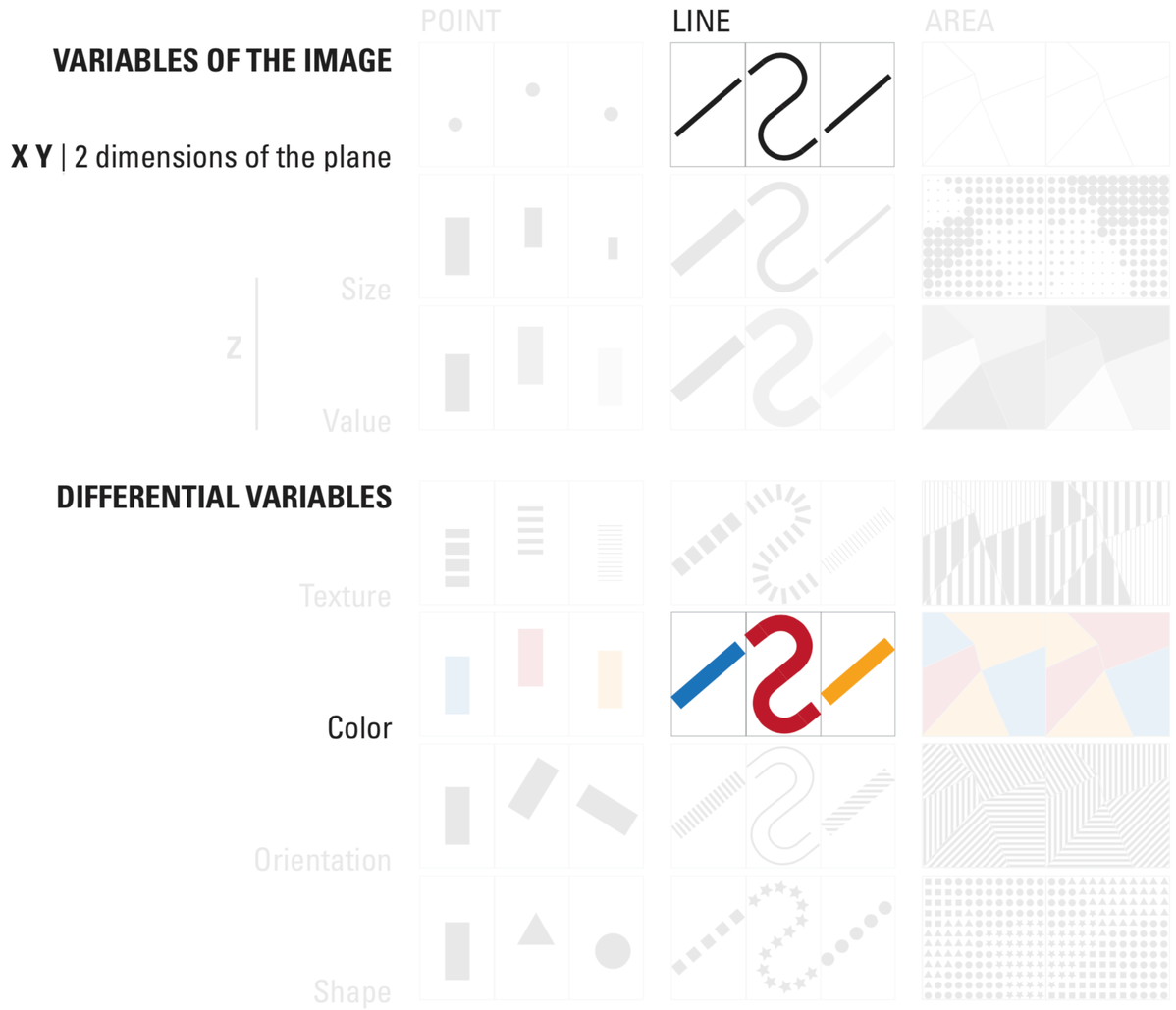

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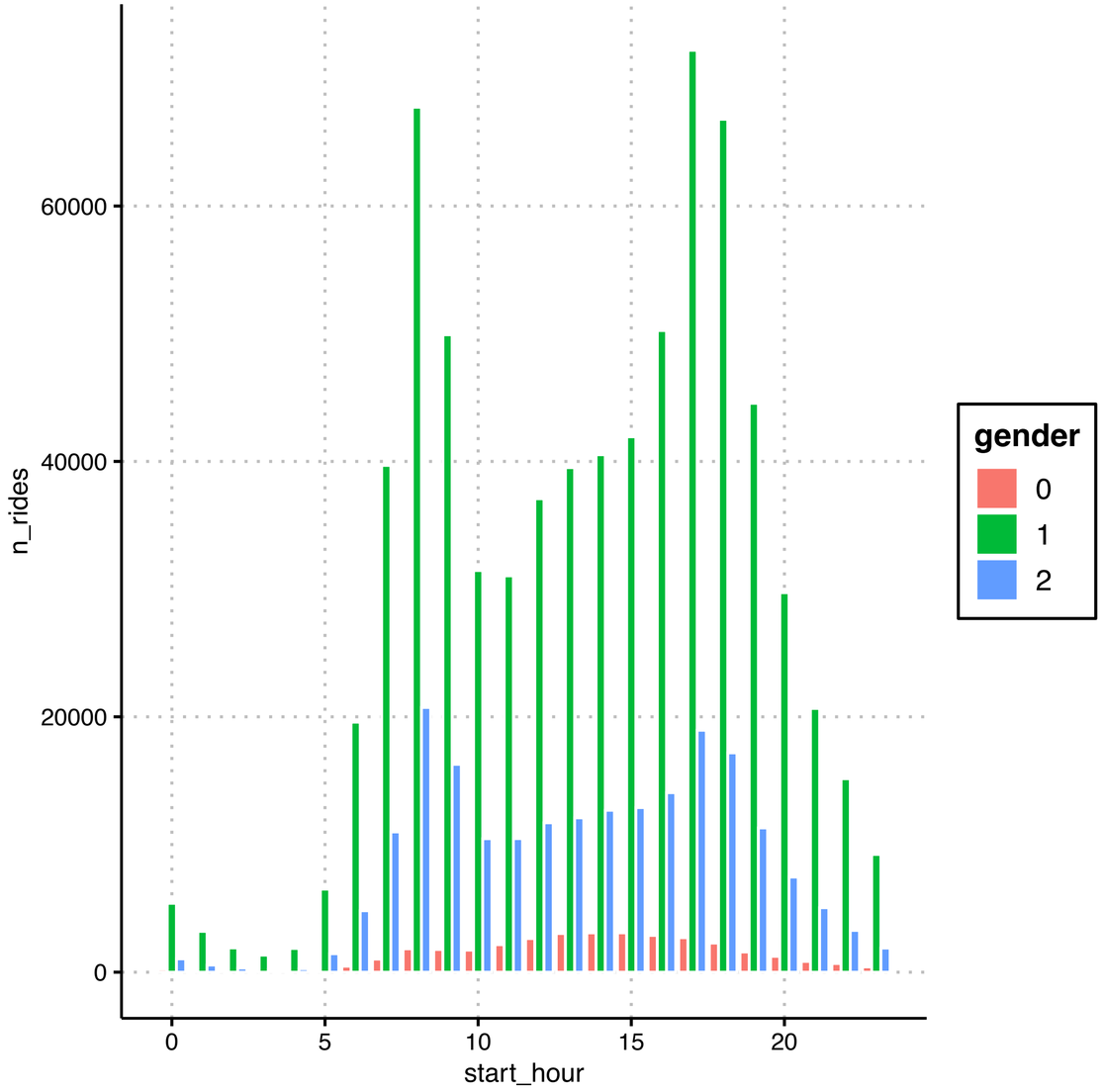
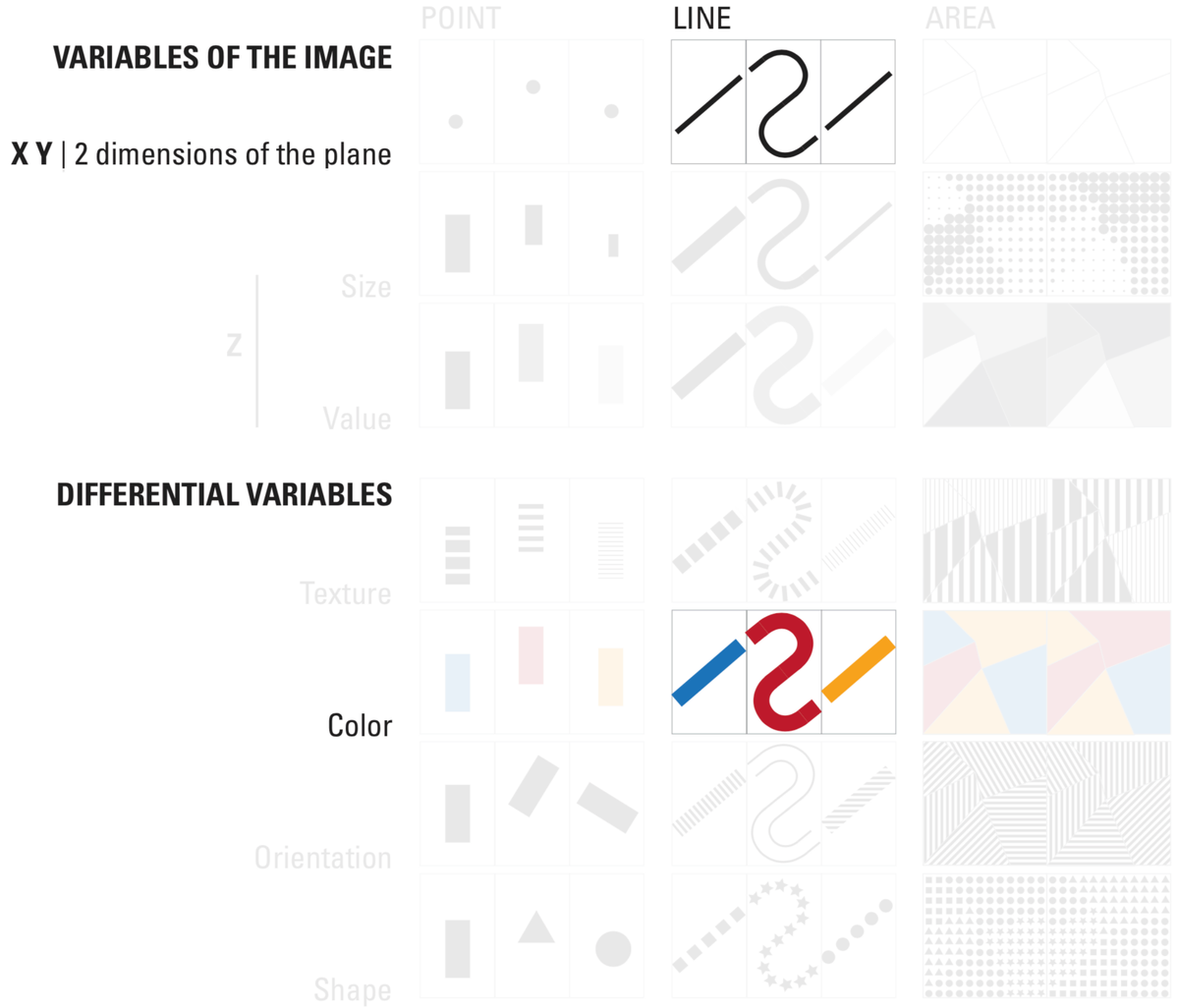
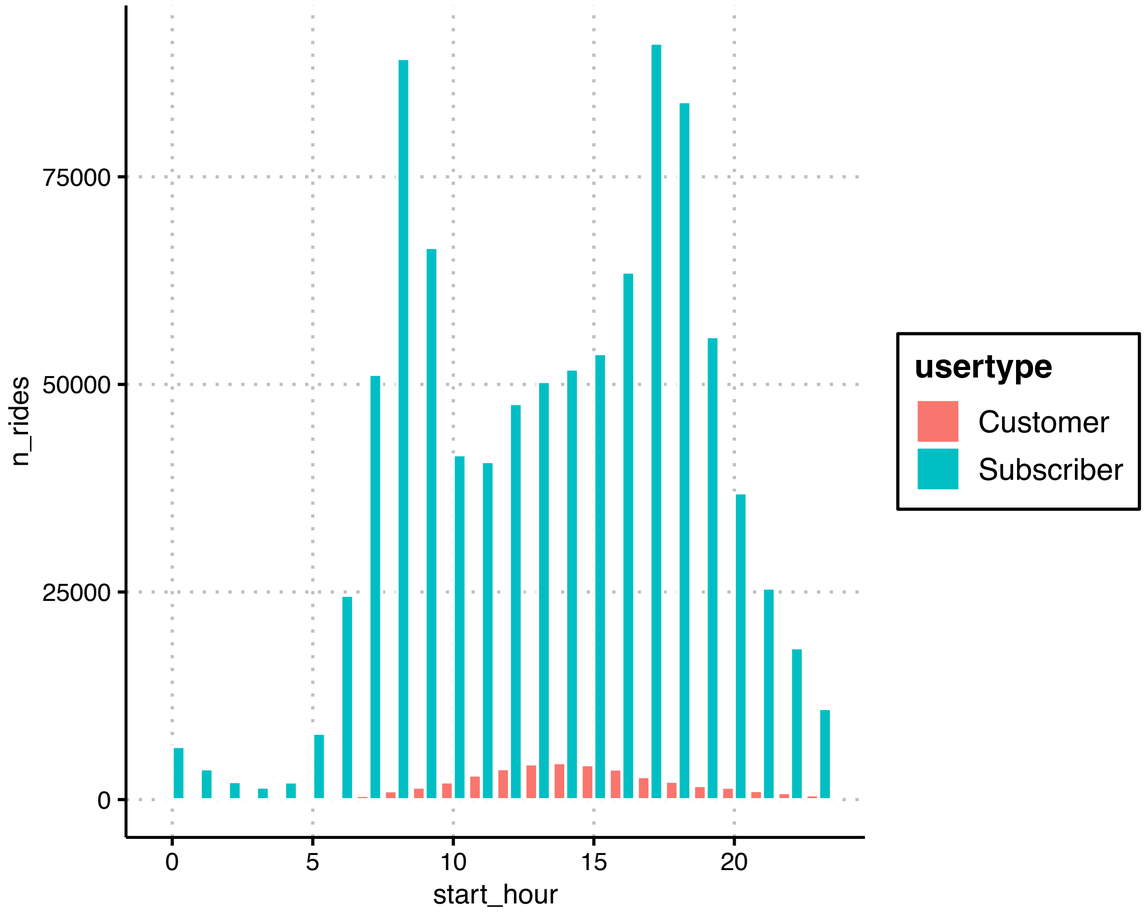


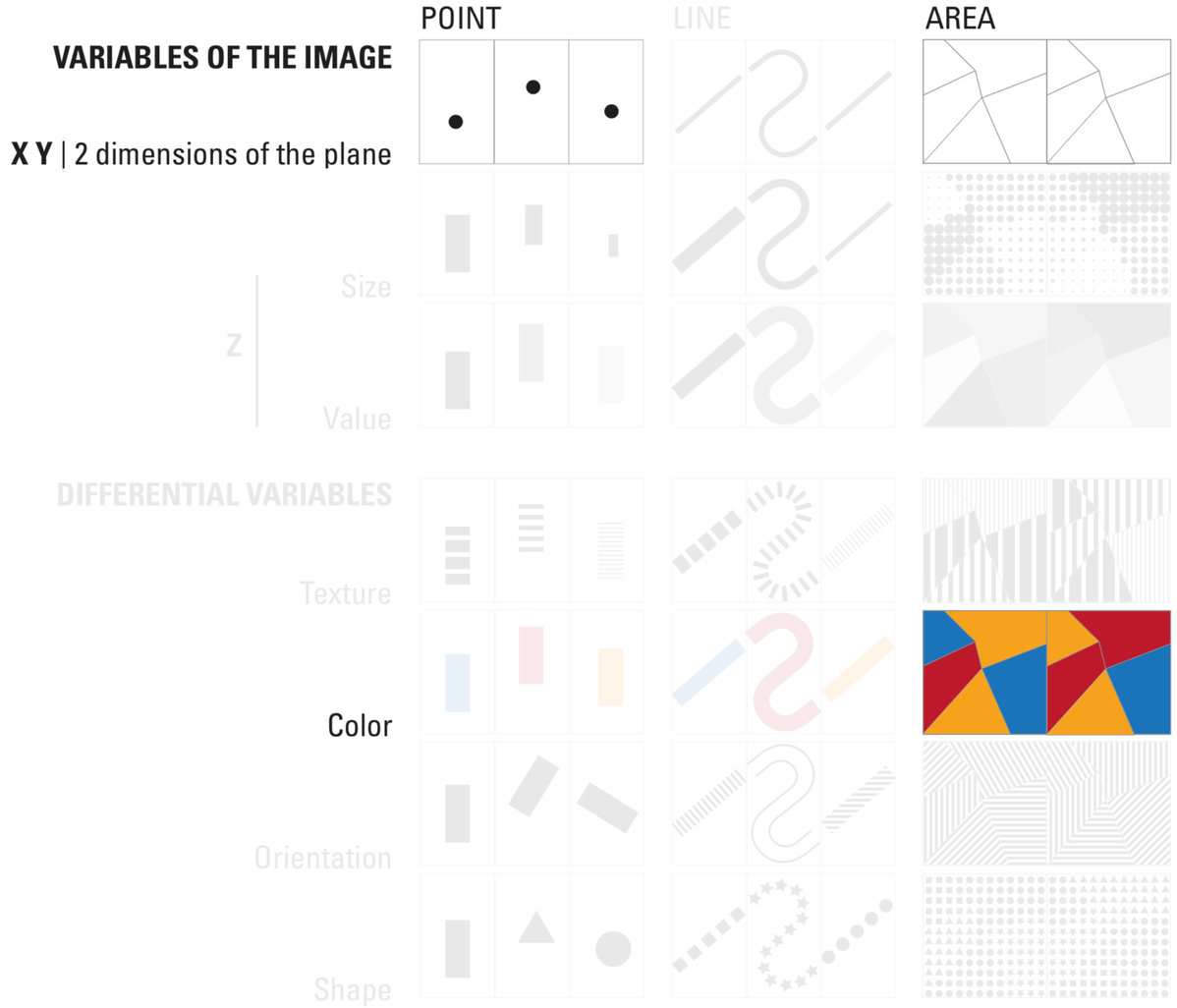
data encodings, visual channels for encoding data



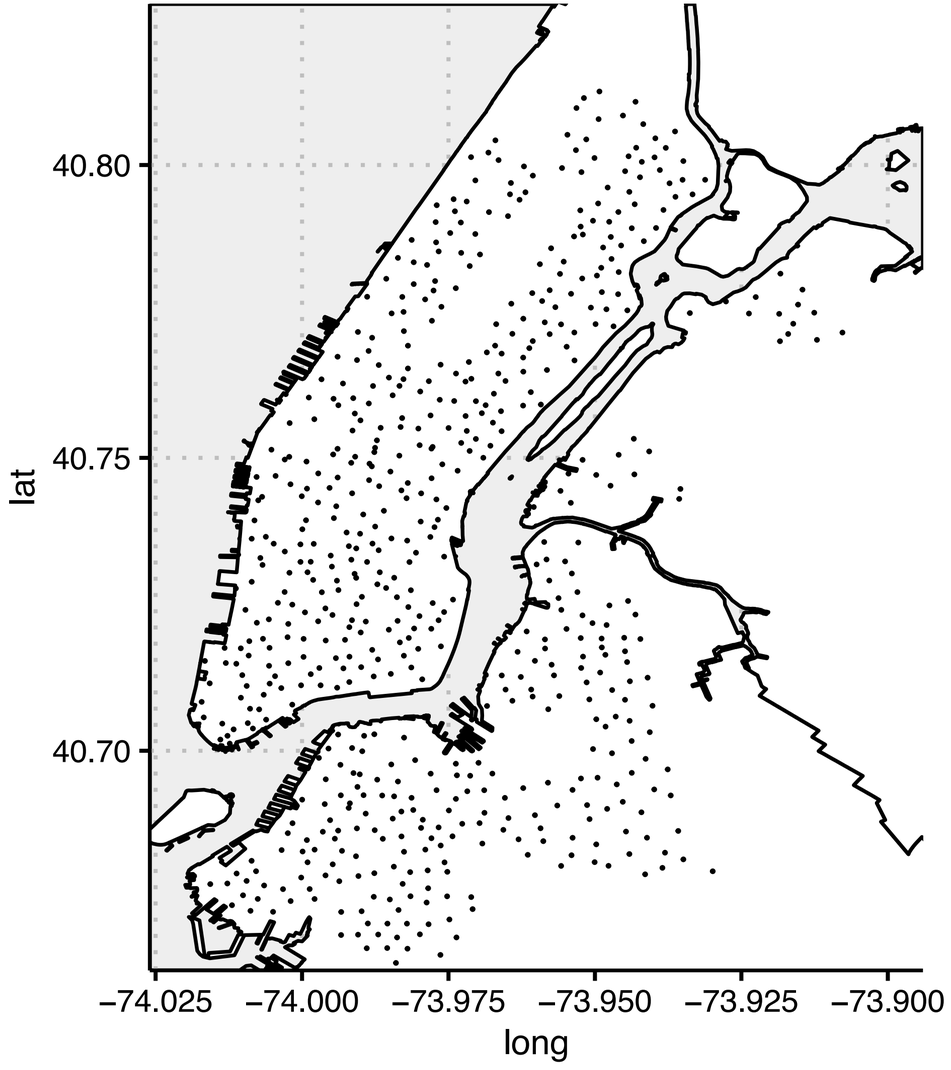
Citi Bike example — *exploratory data analysis*



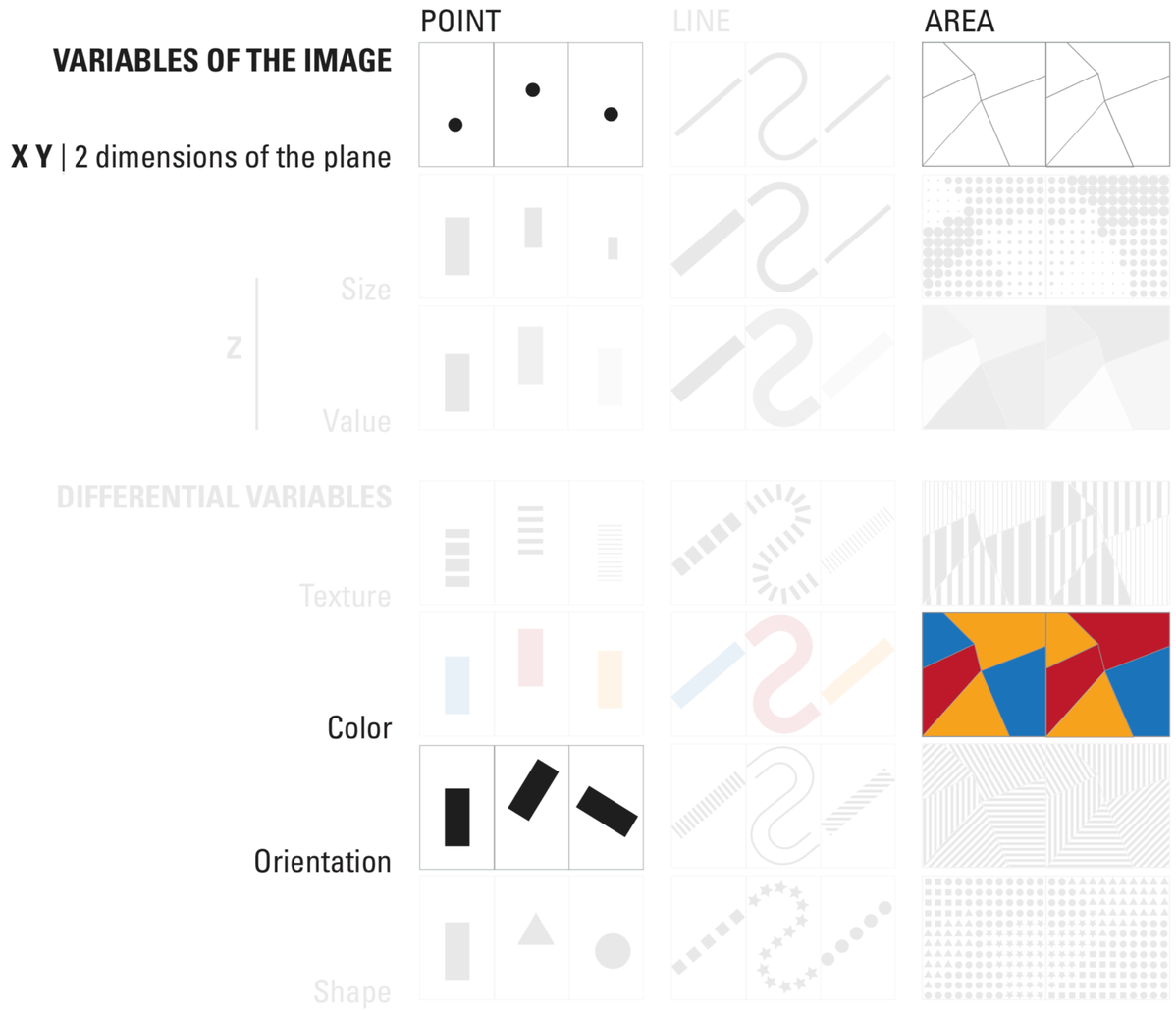
data encodings, visual channels for encoding data



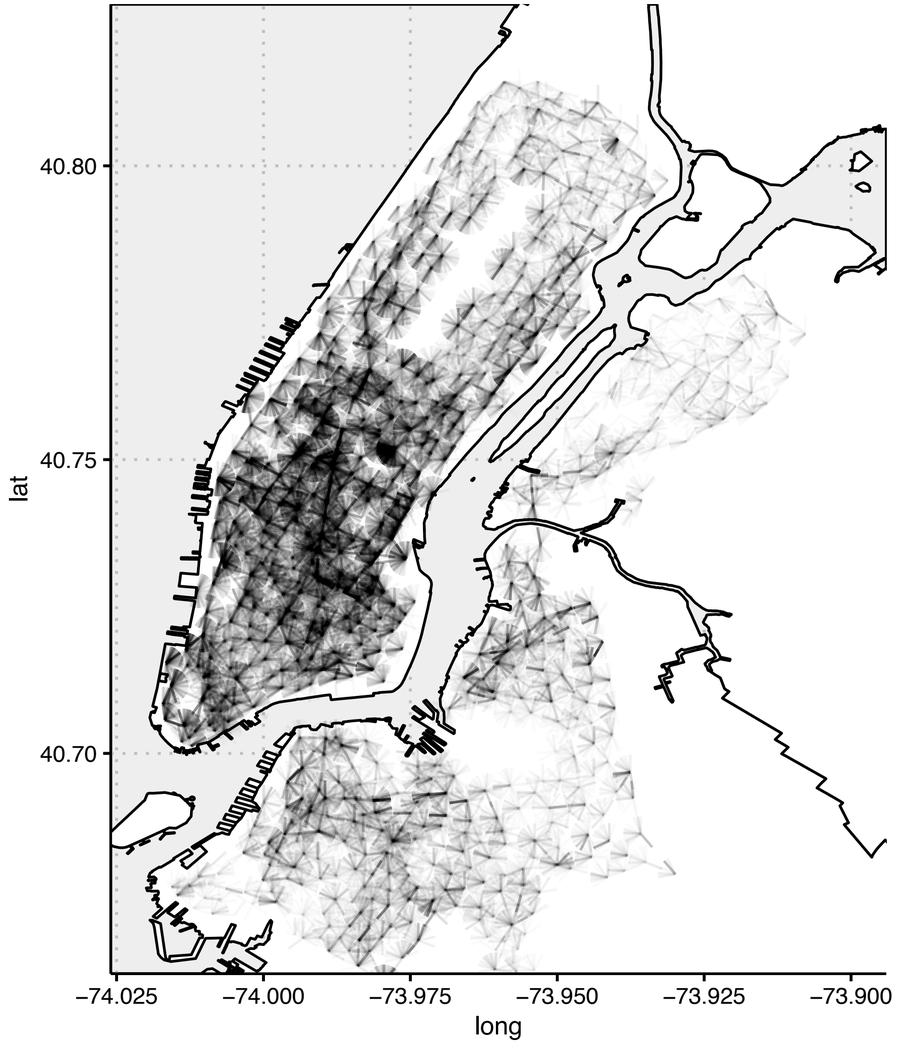
Citi Bike example — *exploratory data analysis*



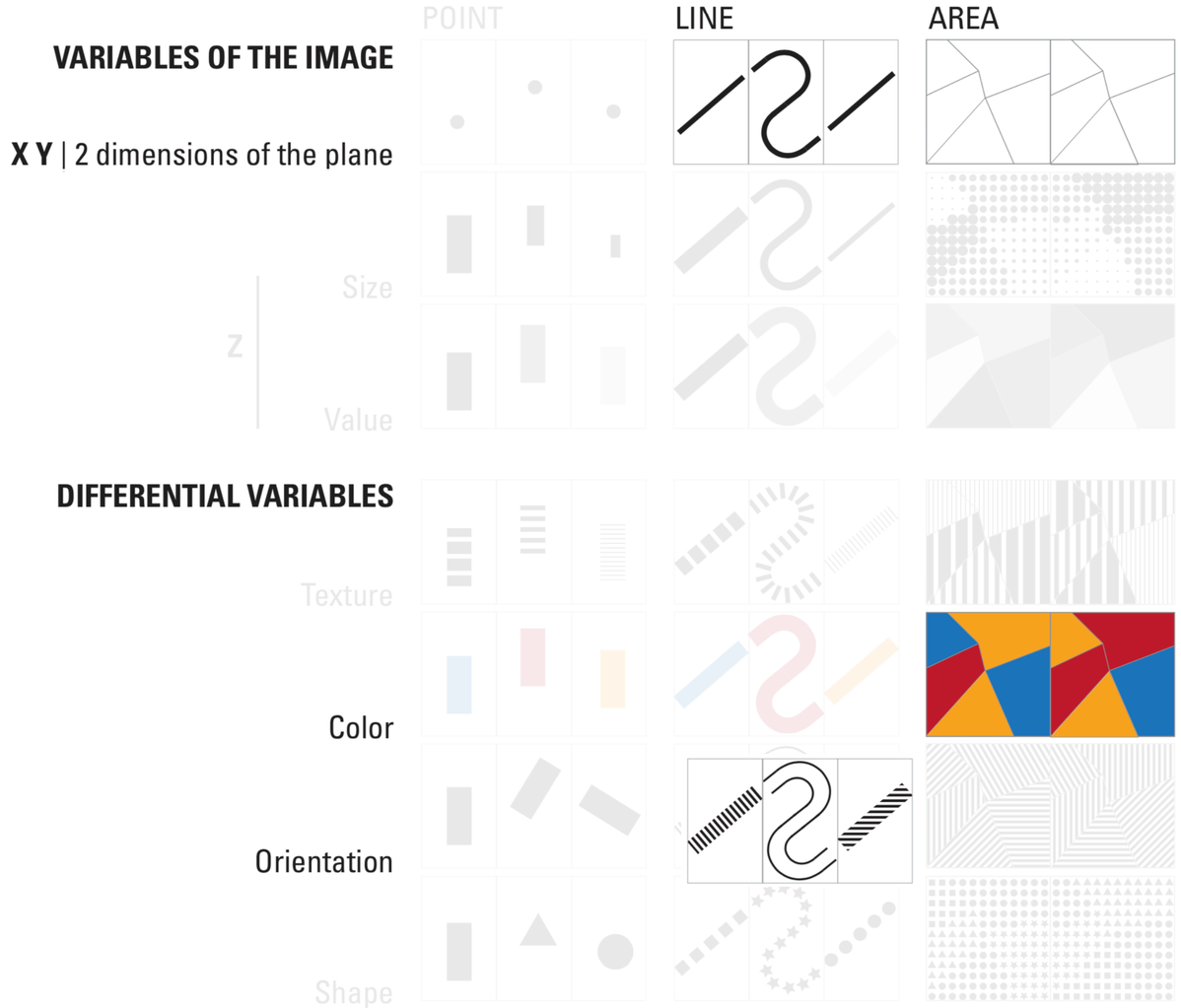
data encodings, visual channels for encoding data



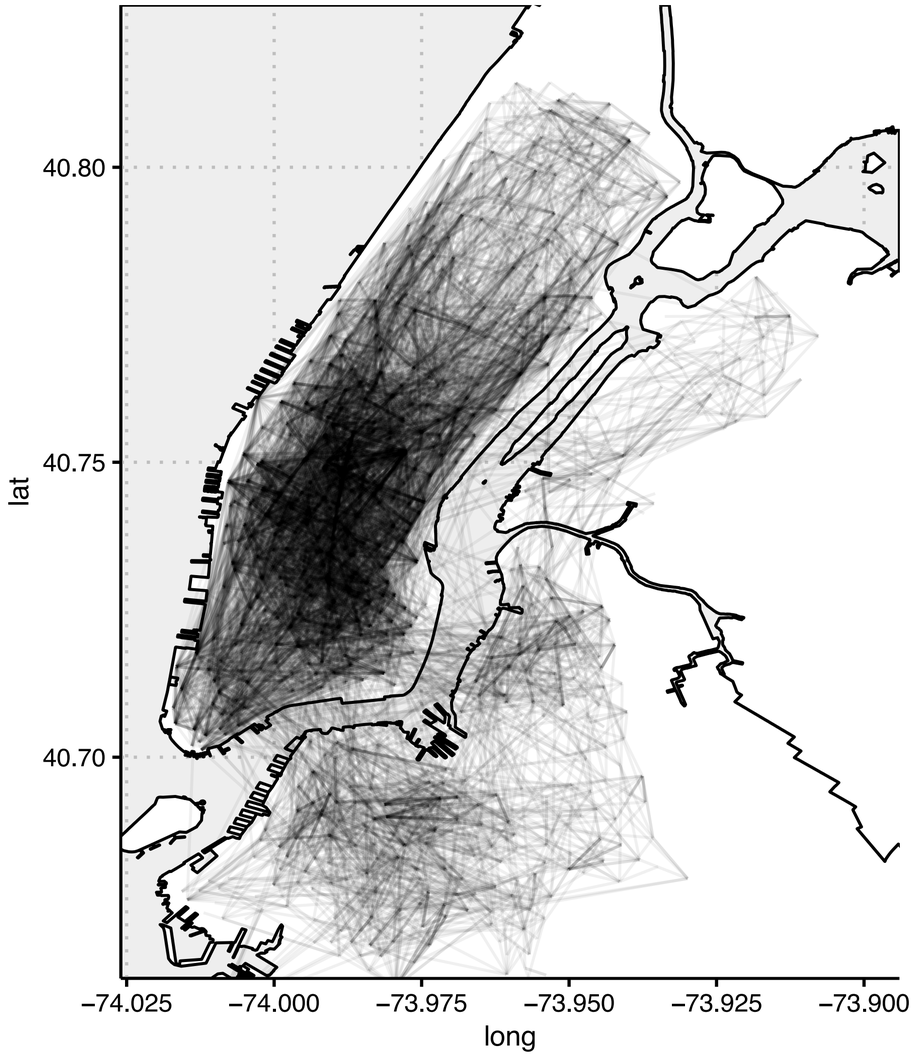
Citi Bike example — *exploratory data analysis*



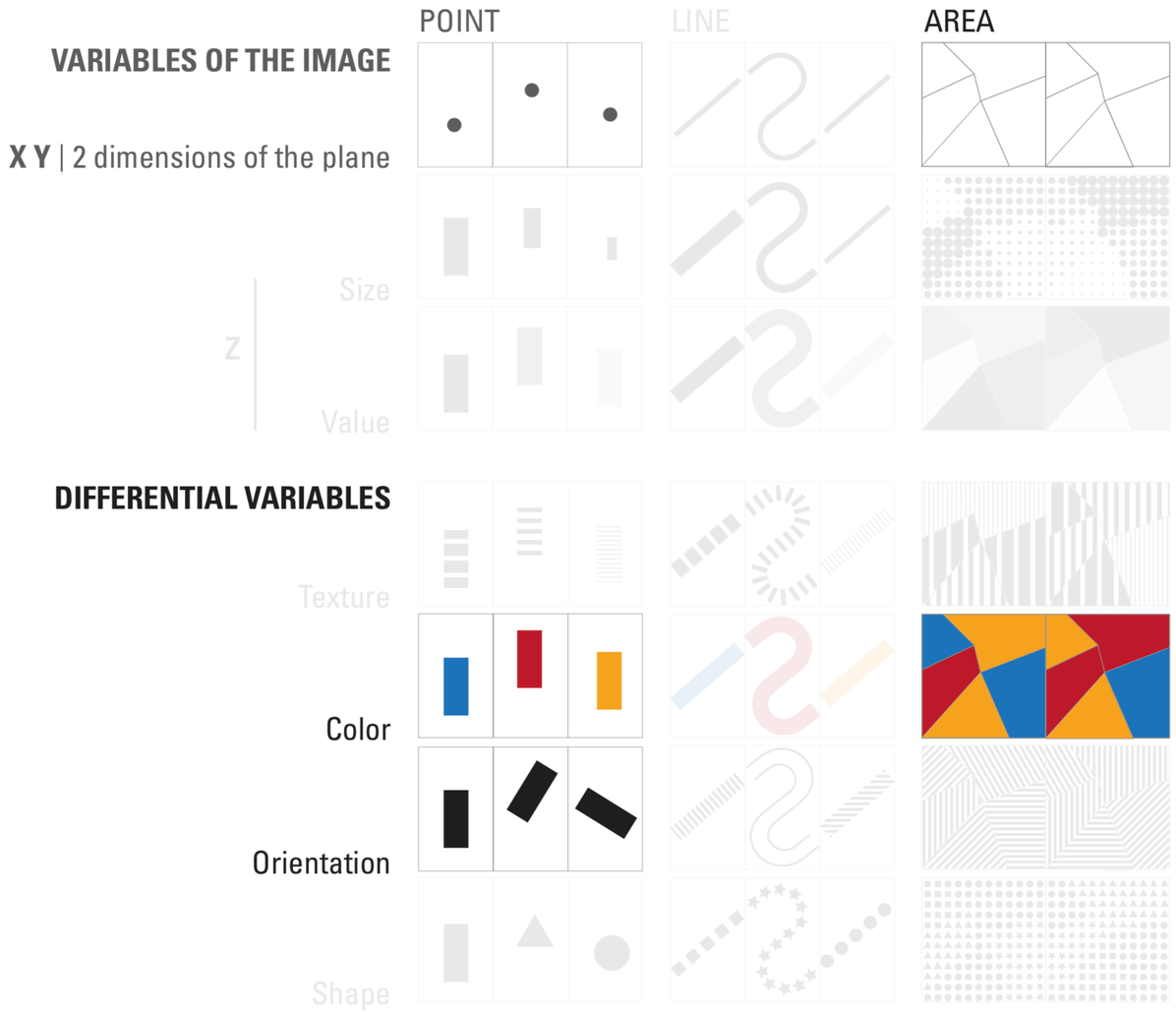
data encodings, visual channels for encoding data



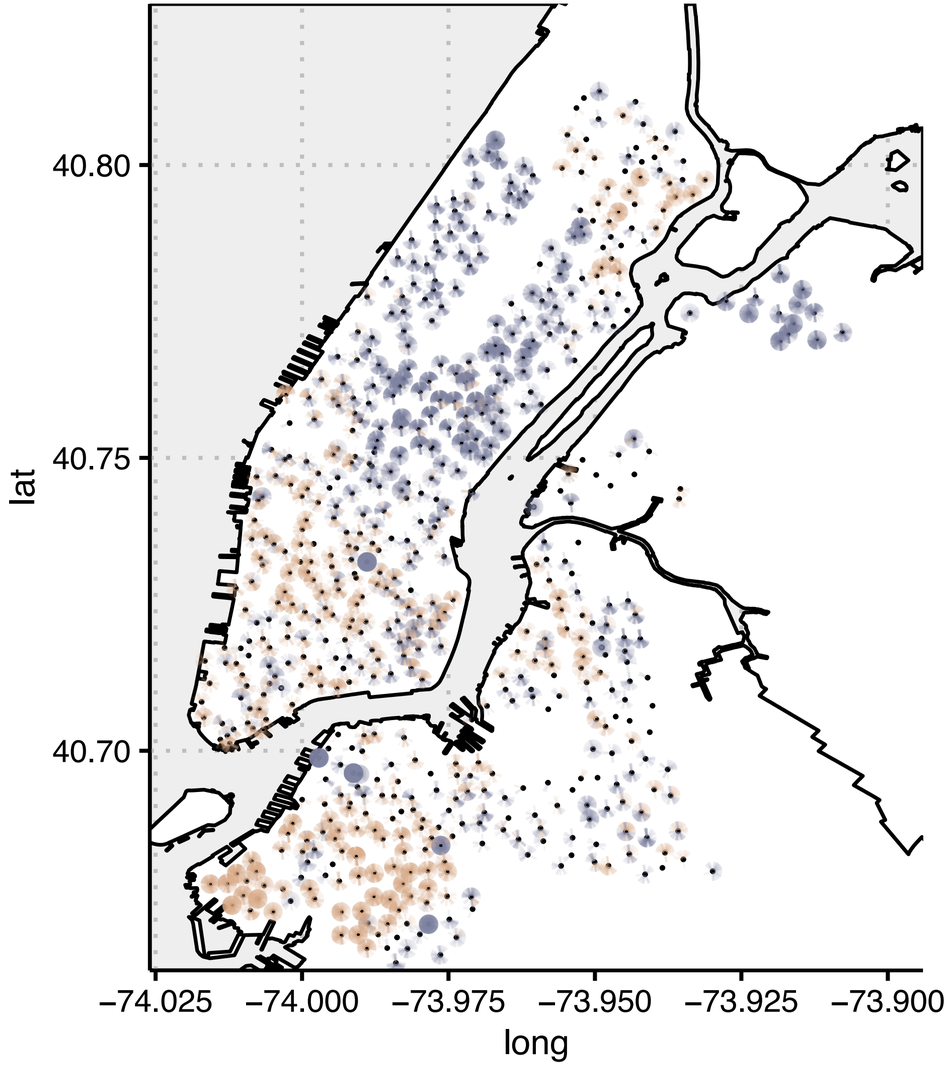
Citi Bike example — *exploratory data analysis*



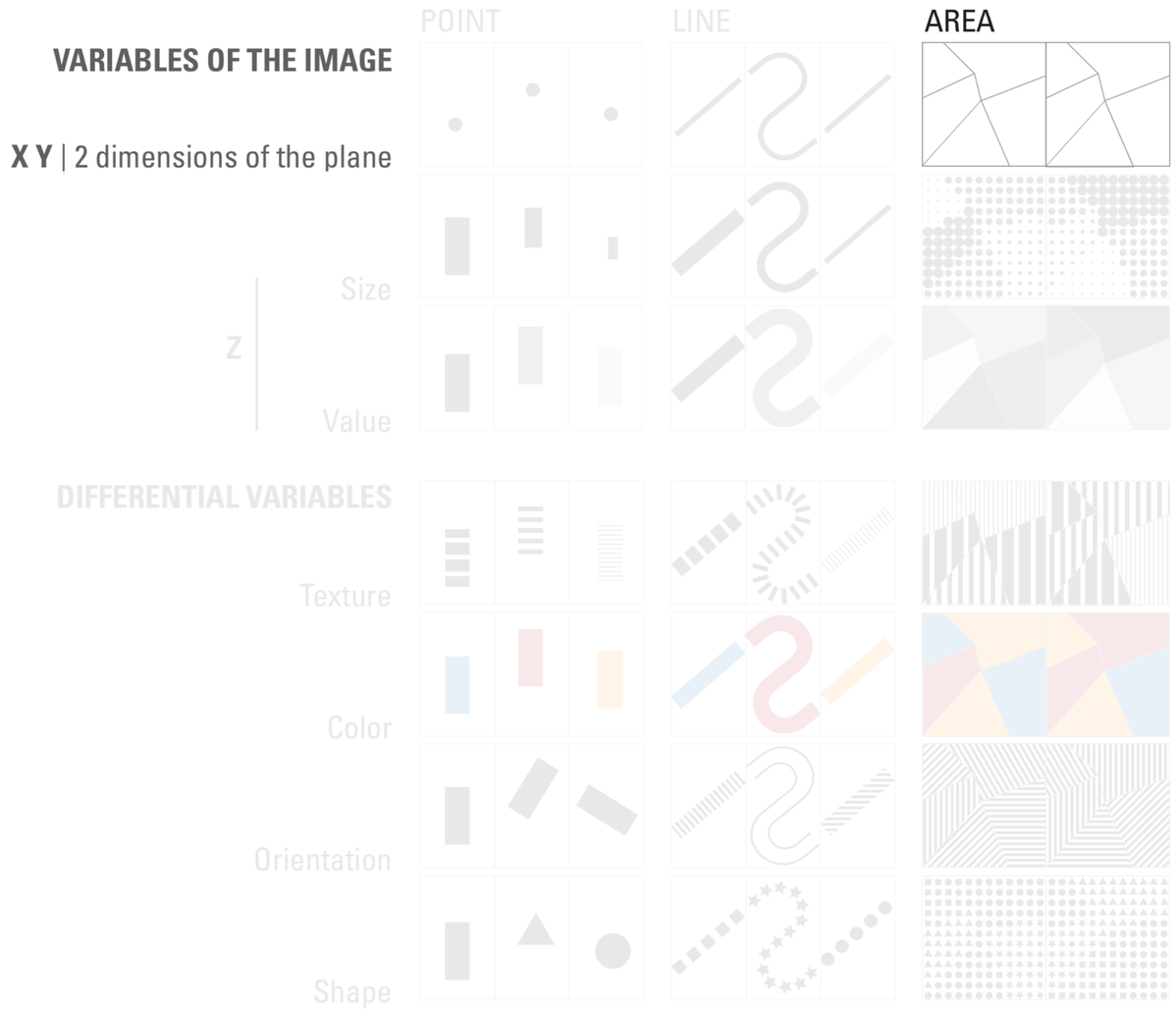
data encodings, visual channels for encoding data



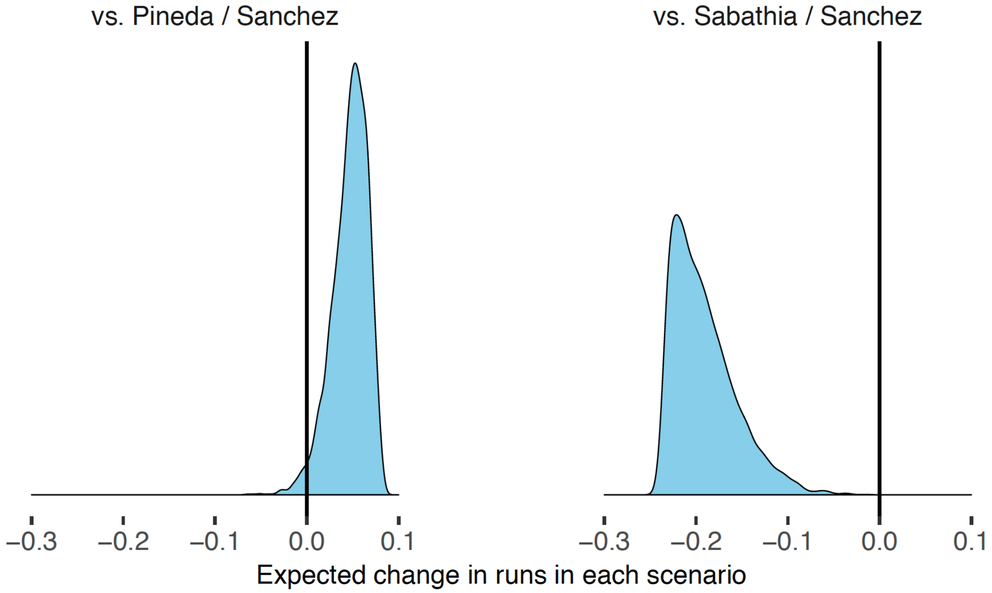
Citi Bike example — *exploratory data analysis*



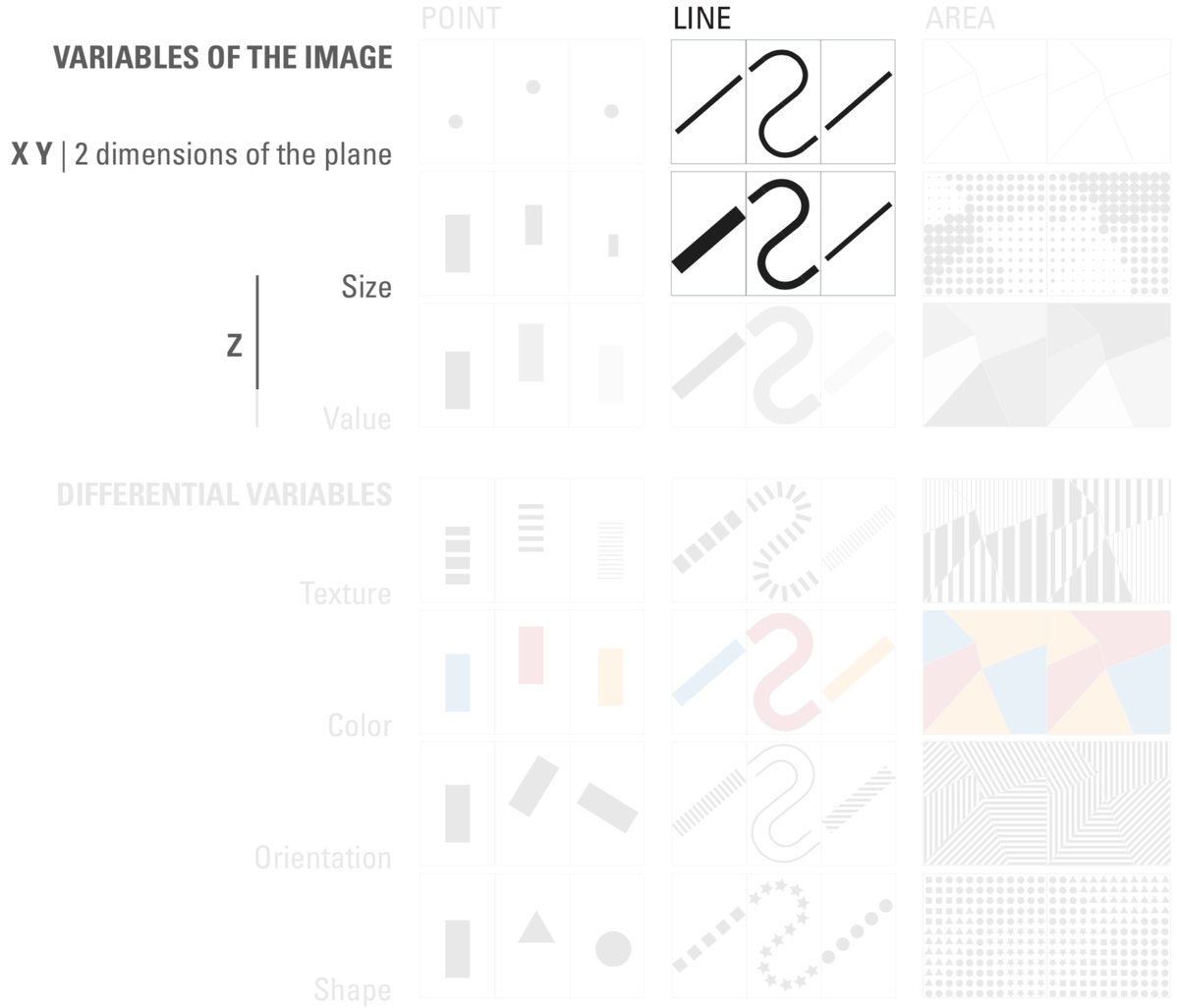
data encodings, visual channels for encoding data



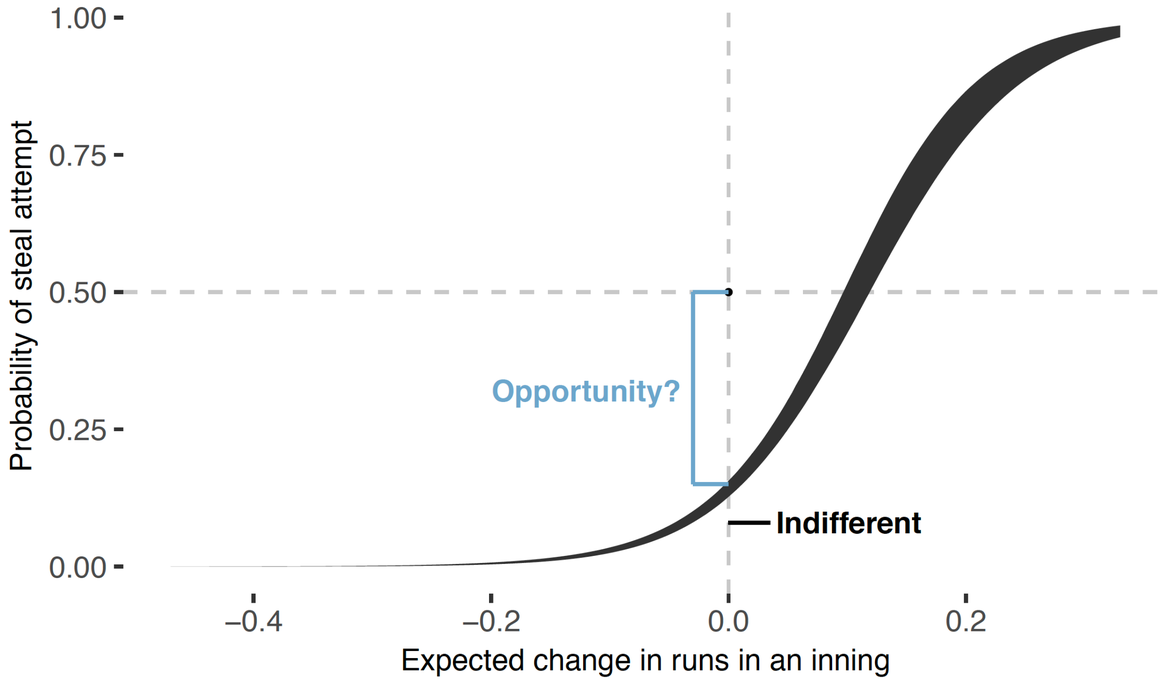
Dodgers *draft* proposal example



data encodings, visual channels for encoding data

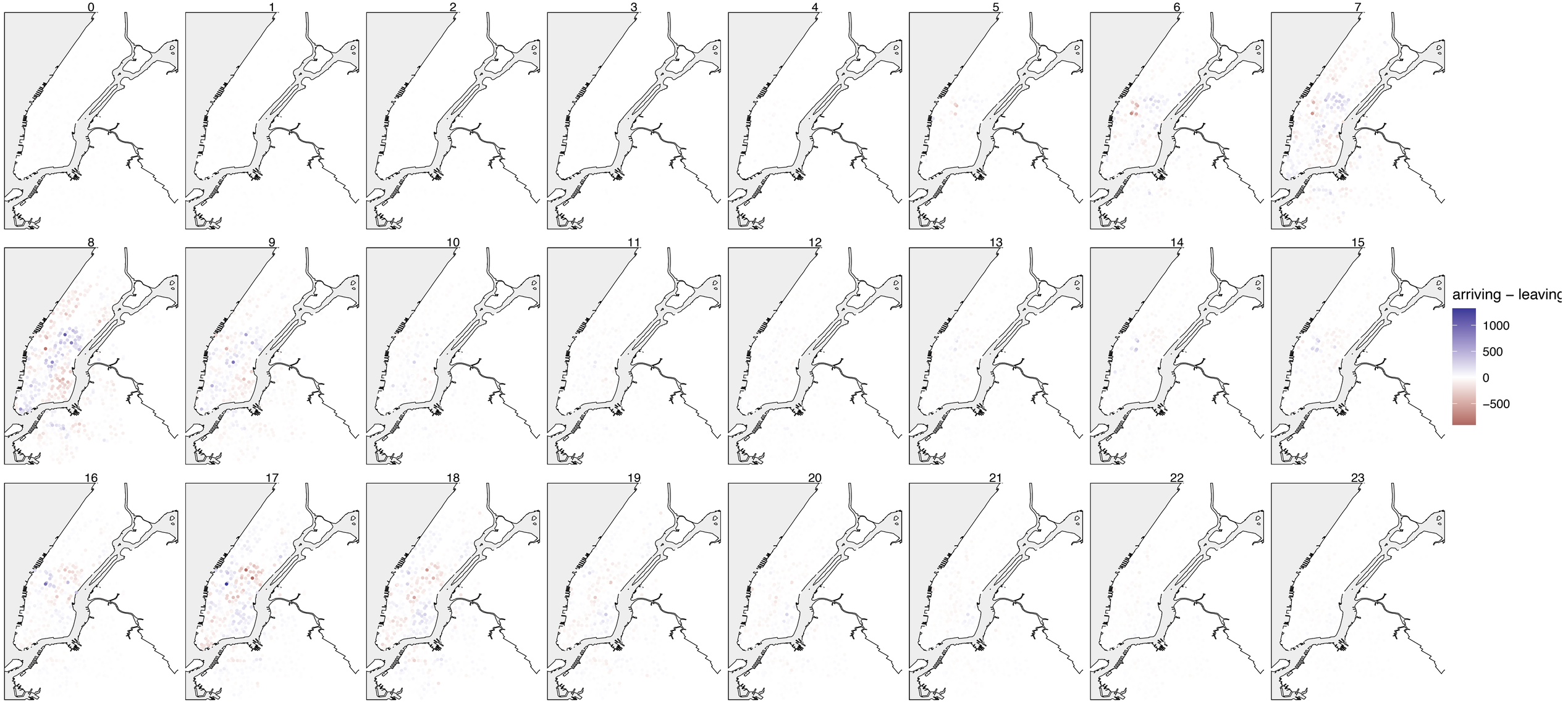


Dodgers *draft* proposal example



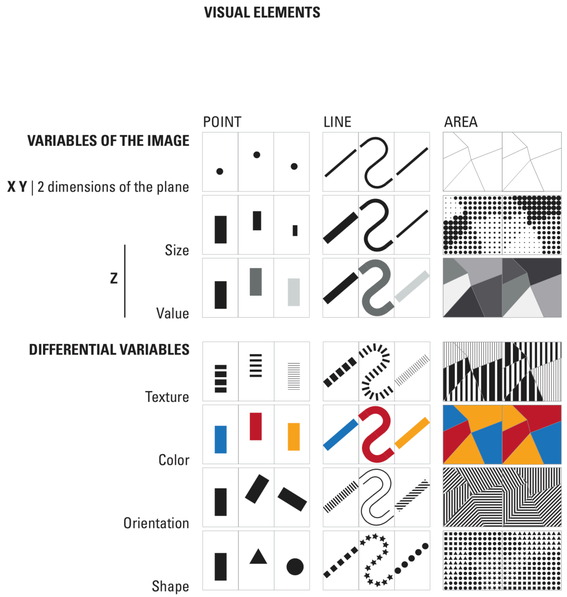
adding dimensions through small multiples

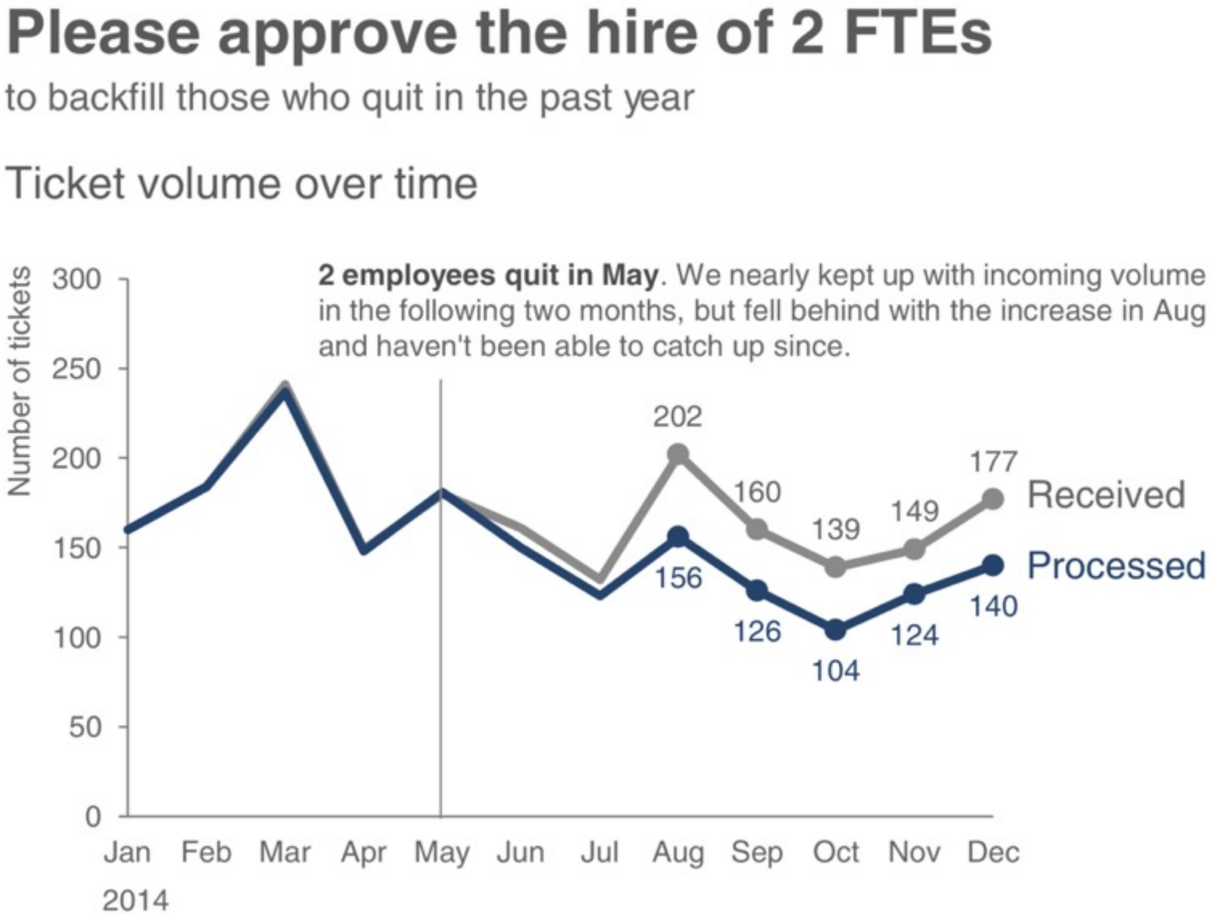
Citi Bike example — *exploratory data analysis*



class exercises

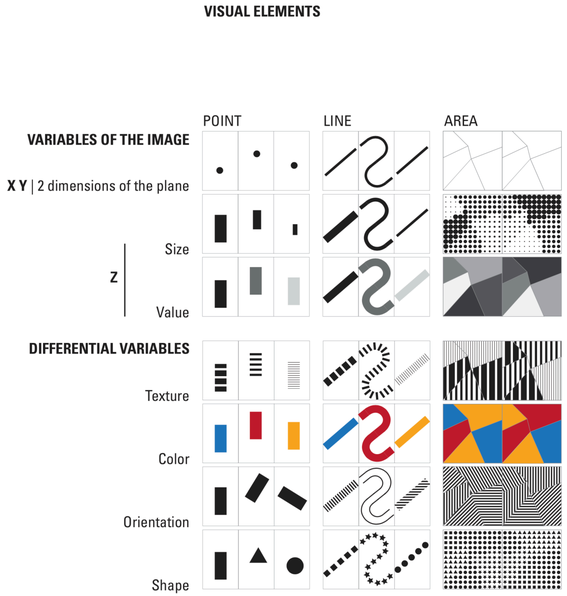
exercise, identify data encodings in visual channels

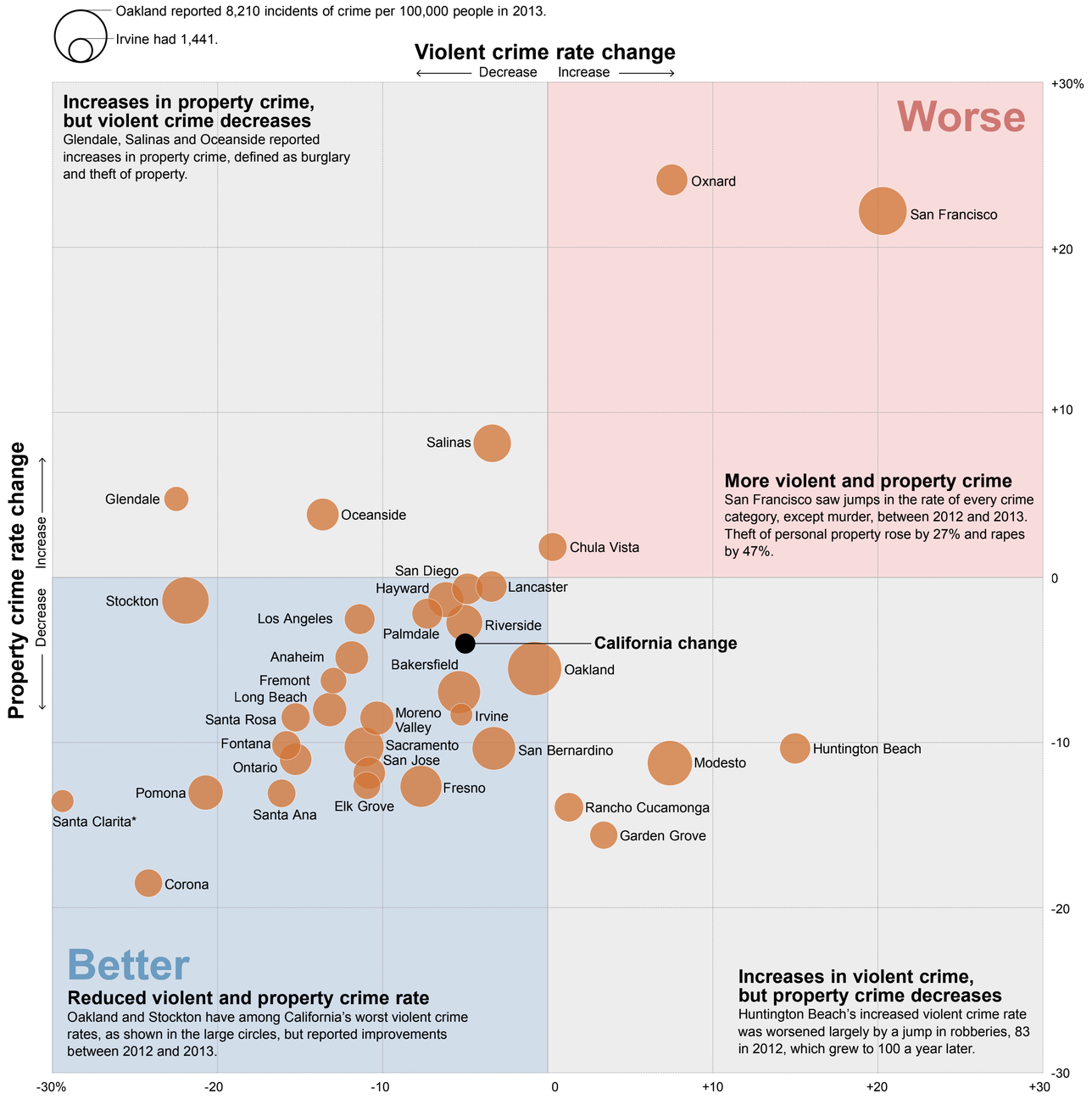




— Knaflic, Cole Nussbaumer. *Storytelling with Data. A Data Visualization Guide for Business Professionals*. Wiley, 2015.

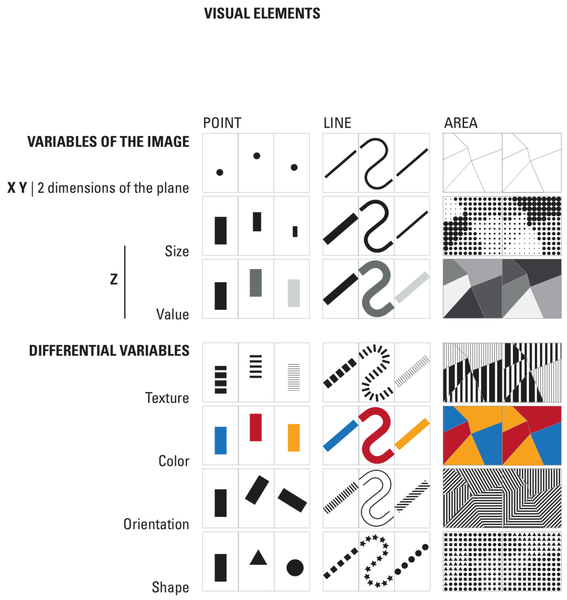
exercise, identify data encodings in visual channels

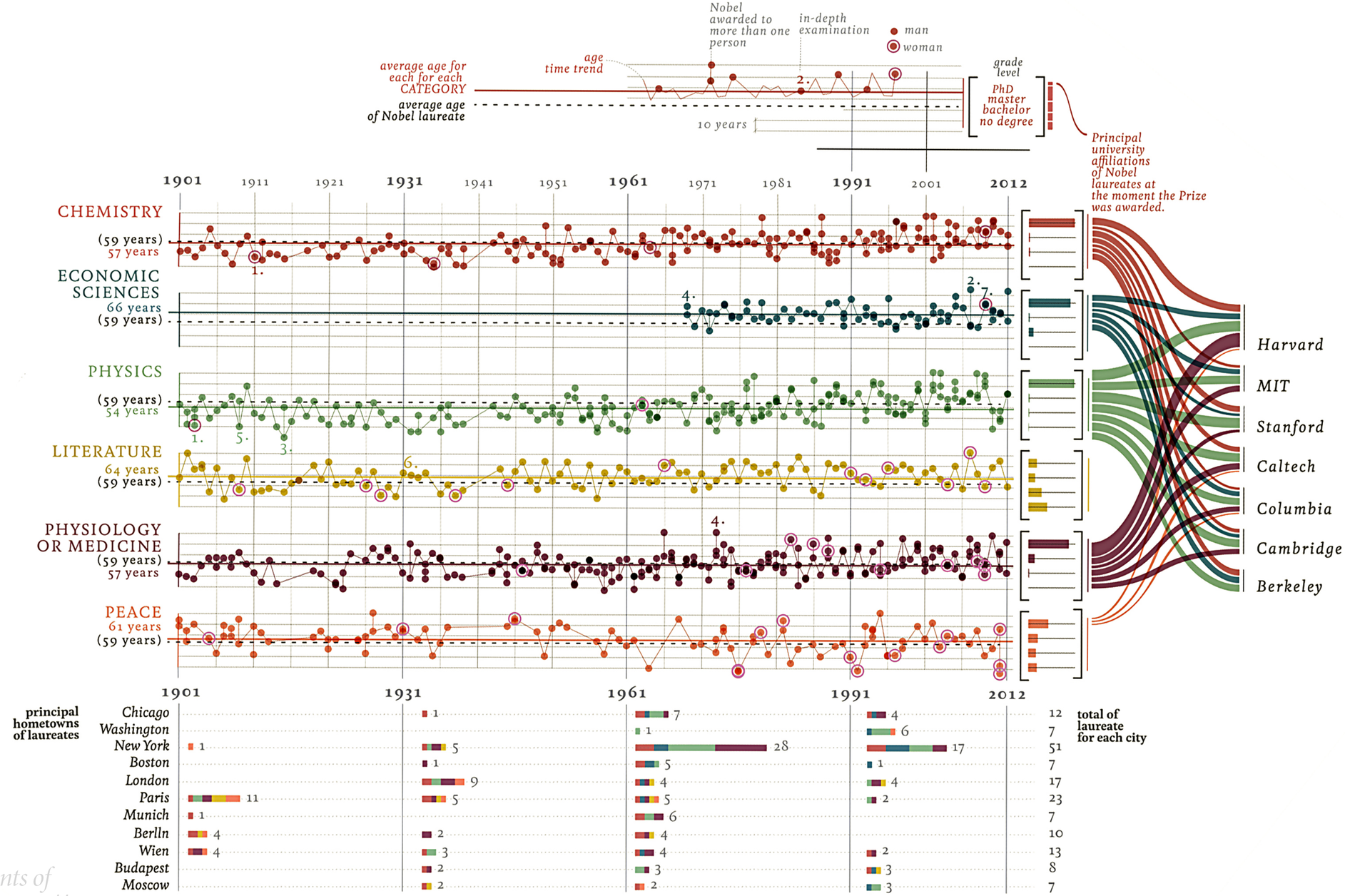




Schleuss, Jon, and Rong-Cong Lin II. 2013. "*California Crime 2013.*" Los Angeles Times.

exercise, identify data encodings in visual channels



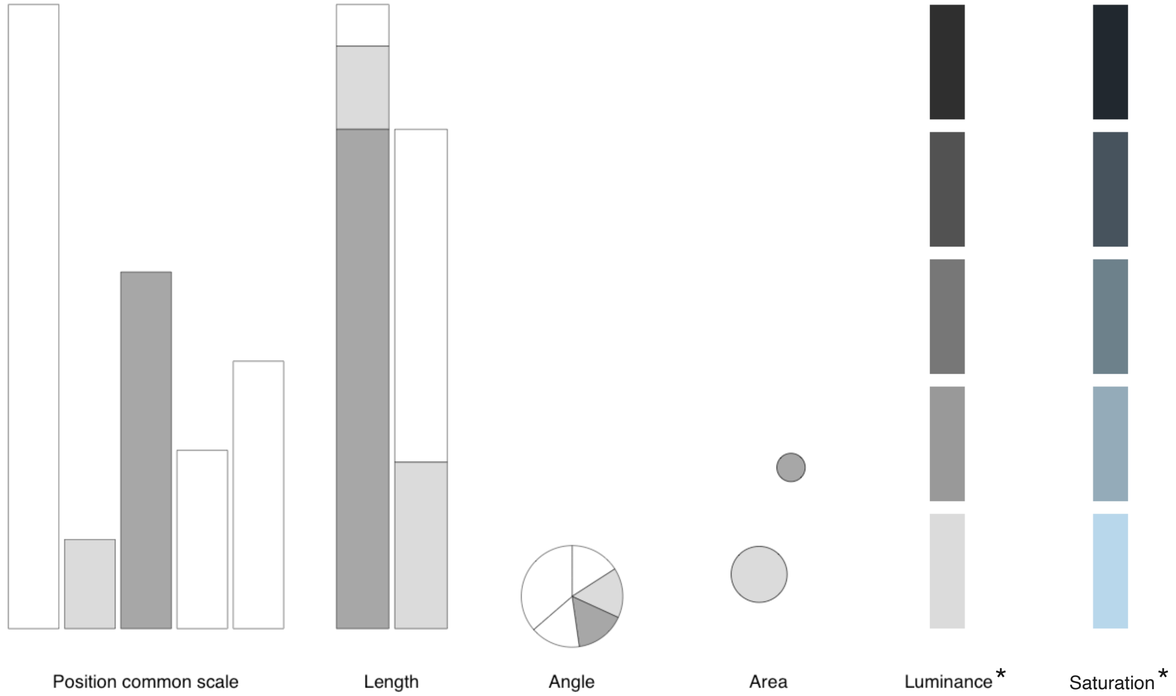


Spencer, Scott. *Approximating the Components of Lupi's Nobels, No Degrees*. March 15, 2019. https://ssp3nc3r.github.io/post/approximating-the-components-of-lupi-s-nobel-no-degrees/.

channel effectiveness for encoding data

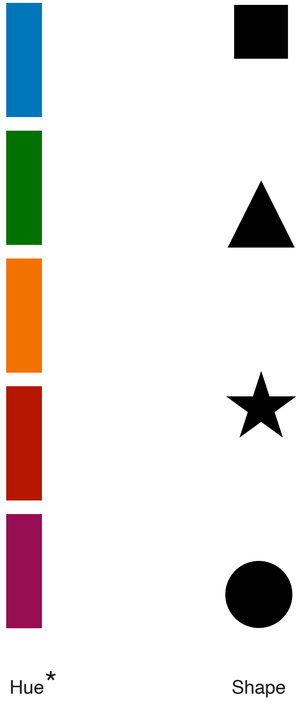
general channel effectiveness, encoding data

ratio, interval, and ordered



more effective ⟷ less effective

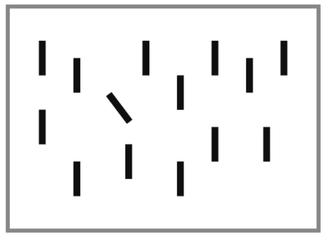
categorical



more effective ⟷ less effective

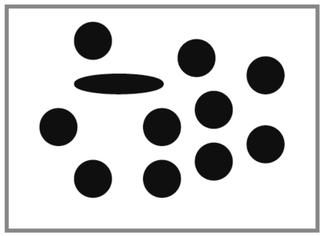
perceptual psychology

Orientation

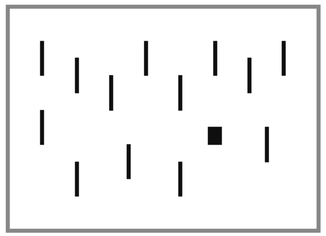


Curved straight

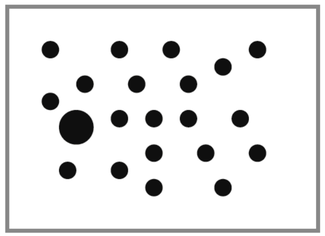
Shape



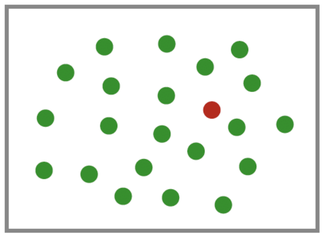
Shape



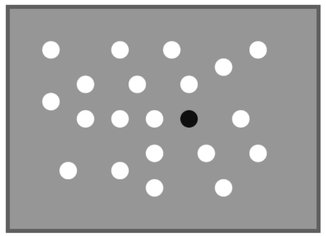
Size



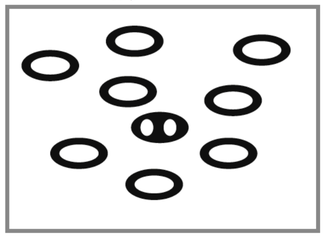
Color



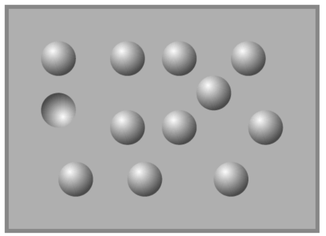
Light/dark



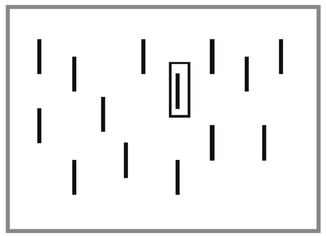
Topology (or count)



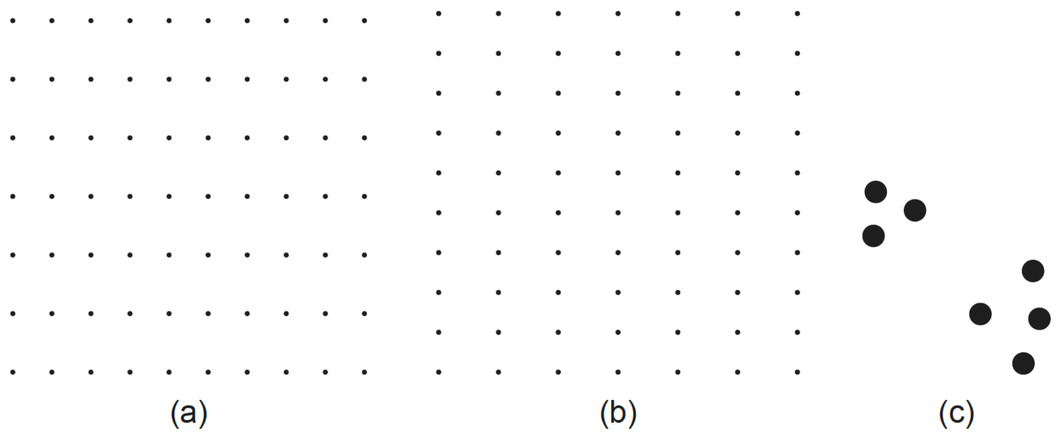
Convex/concave



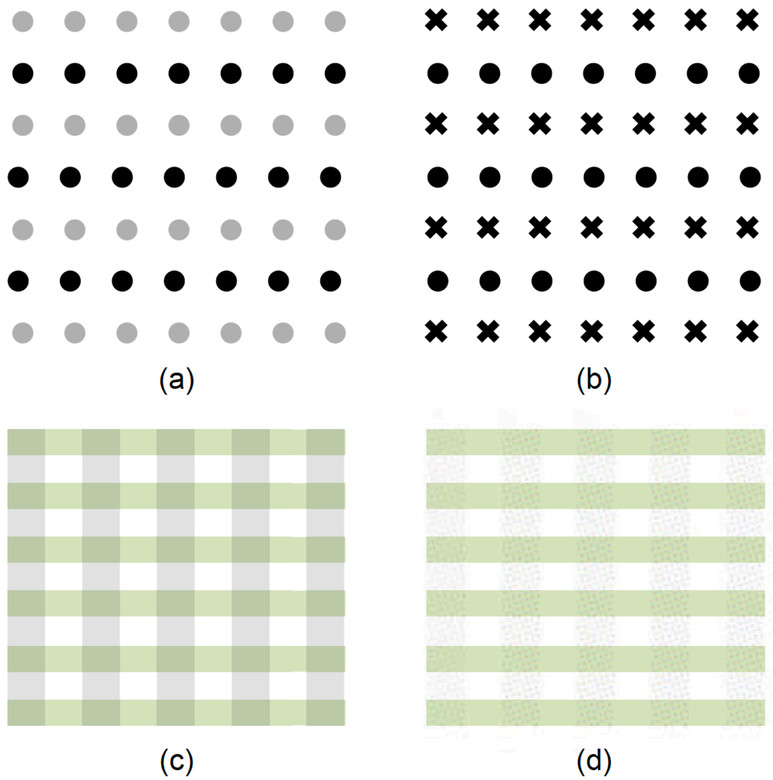
Addition



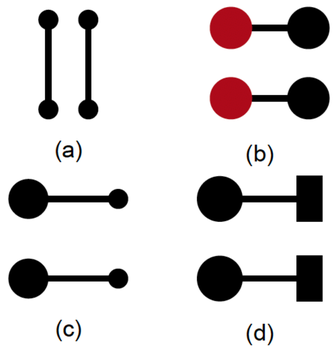
 Gestalt principles, *proximity*



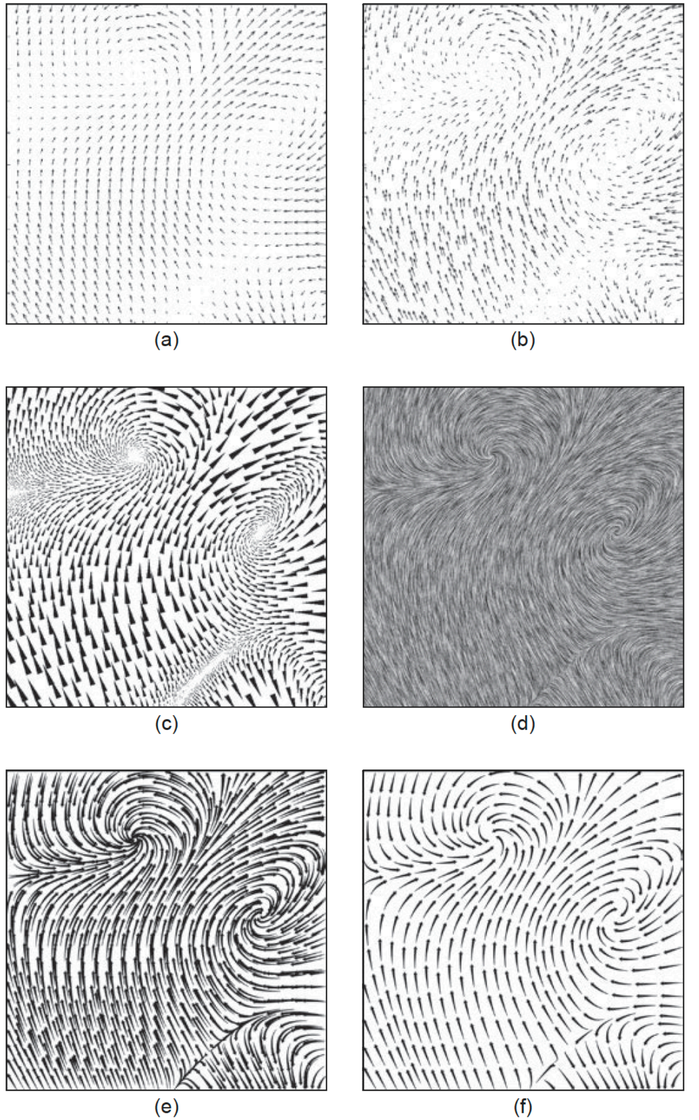
 Gestalt principles, *similarity*



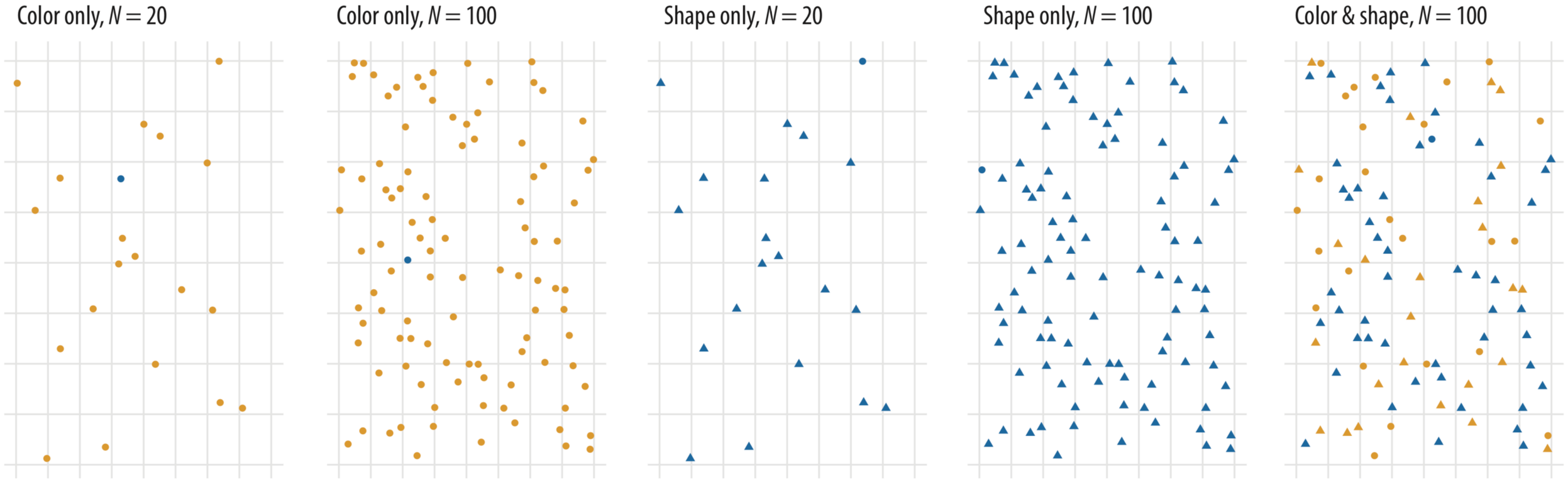
 Gestalt principles, *connectedness*



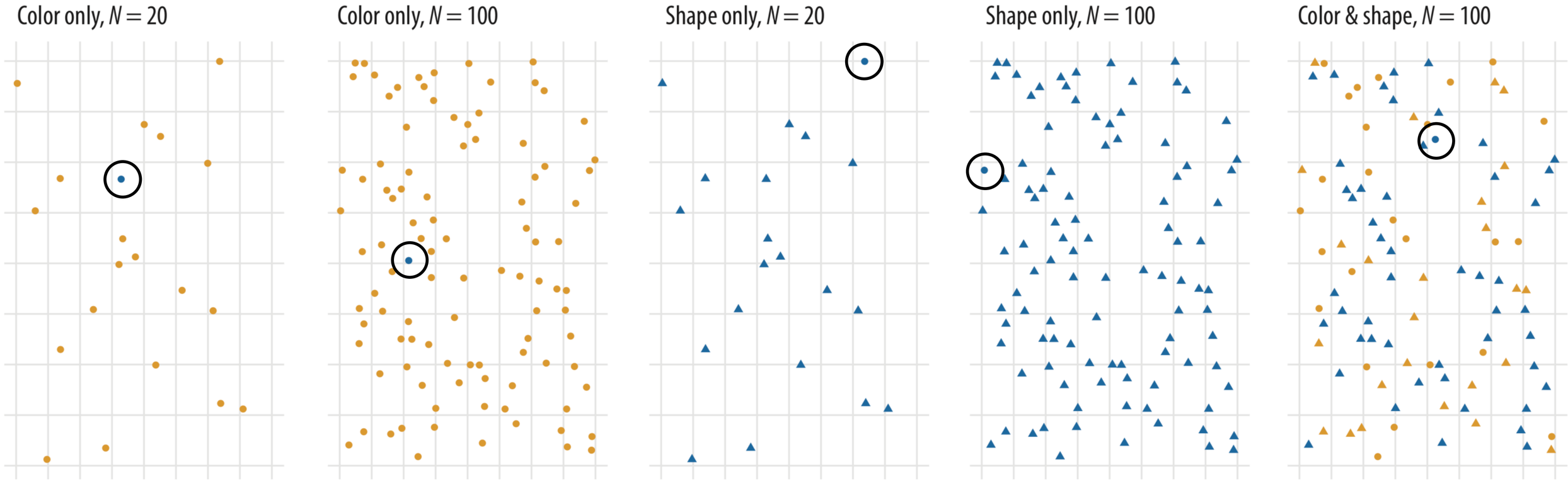
perceptual psychology, Gestalt principles, *orientation, magnitude, direction*



perceptual psychology, **example — *focusing visual attention***



 example — *focusing visual attention*



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.