COGS138: Neural Data Science

Lecture 9

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(Based on a course created by Prof. Bradley Voytek)

Plan for today

- Announcements
- Assignment 2 overview - due tonight at midnight!
- Review - Last time
- More on Data, Visualization, and outlier detection
- Statistical data analysis, Part 1
- Group projects introduction

Announcements

- A2 - due **Friday 5/5**
- Reading 2 - Released on canvas and in web site password protected area soon, lecture quiz due next **Tuesday 5/9 R2 quiz**
- **Group formation** - check canvas for empty groups, please self-sign up
- Previous project review released when we get the groups together (this week)
- Podcasts added to webpage along with several links to readings

Last time

Course links

Website	http://casimpkinsjr.radiantdolphinpress.com/pages/cogs138_sp23	Main face of the course and everything will be linked from here. Lectures, Readings, Handouts, Files, links
GitHub	https://github.com/drsimpkins-teaching	files/data, additional materials & final projects
datahub	https://datahub.ucsd.edu	assignment submission
Piazza	https://piazza.com/ucsd/spring2023/cogs138_sp23_a00/home (course code on canvas home page)	questions, discussion, and regrade requests
Canvas	https://canvas.ucsd.edu/courses/44897	grades, lecture videos
Anonymous Feedback	Will be able to submit via google form	If I ever offend you, use an example you are uncomfortable with, or to provide general feedback. Please remain constructive and polite

A quick overview of one possible data cleaning process example

1. View your data (EDA) - commands (‘print()’, ‘dataFrame.head()’, ‘dataFrame.shape’)

2. Compute the missing proportions of data (NANs etc)

3. View each column data type, format, content

4. Check for trailing white spaces in text, eliminate characters that are irrelevant (punctuation, symbols, etc)

5. Explore if any columns need to be split or combined

6. Check uniqueness of values (sanity check)

Visualization of neural data

- https://mne.tools/stable/auto_tutorials/evoked/20_visualize_evoked.html

- https://mne.tools/stable/auto_tutorials/inverse/70_eeg_mri_coords.html#sphx-glr-auto-tutorials-inverse-70-eeg-mri-coords-py

To the notebook overview

Visualization

- **Tools**:
    - seaborn - generating plots
    - pandas - wrangling data
    - matplotlib - fine-tuning plots
- **Plotting**
    - quantitative data
    - categorical data
- **Customizing visualizations**

On to today…

“Data science is the process of formulating a quantitative question that can be answered with data, collecting and cleaning the data, <u>analyzing the data</u>, and communicating the answer to the question to a relevant audience.”

To do this, you have to *look at, describe, and explore* the data

Summary: Analytical Approaches

1. Descriptive (and Exploratory) Data Analysis are the first step(s)
2. Inference establishes relationships
   a. Classic Statistics
   b. Geospatial Analysis
   c. Text Analysis
3. Machine Learning is for prediction
   a. Supervised
   b. Unsupervised
4. Experiments best way to establish the likelihood of causality
   a. Remember you ***cannot*** establish causality with computational methods only correlations along with statistical beliefs

Did they summarize the data?
Yes
Did they report the summaries without interpretation?
No
Did they quantify whether the discoveries are likely to hold in a new sample?
Yes
Are they trying to figure out how changing the average of one measurement affects another?
No
Yes
No
No
Yes
Descriptive
Exploratory
Causal
STOP! Not a data analysis
Classic Statistics (parametric & nonparametric)
Text Analysis
No
Are the data a corpus of text?
Yes
Are they trying to predict measurement(s) for individuals?
No
Yes
Predictive
Inferential
No
Are the observations spatially related?
Yes
Geospatial Statistics
Supervised Machine Learning
Unsupervised Machine Learning
Yes
Did the computer decide the features of your model?
No

Statistical Data Analysis

- There are various definitions
- "Statistics" - the science of gathering data and discovering patterns
- "the science that deals with the **collection, classification, analysis, and interpretation of numerical facts or data**" [dictionary.com]

What are the 2 types of statistics?

What are the 2 types of statistics?

- **Descriptive** - Summarizing the characteristics of data
- **Inferential** - Modeling, making ‘inferences’ from data

Descriptive statistics

- **Summarizing** the **characteristics** of data
  - *Central tendency* - (“center”) mean, median, mode
  - *Variability* - (“dispersion”) variance, standard deviation
  - *Frequency distribution* - (“occurrence within data”) counts
- Charts, plots, probability distribution shapes

Inferential statistics

- “Modeling” or making ‘inferences’ from the data
- Taking data from samples and making predictions about populations
- 2 types
    - *Estimating parameters*
    - *Hypothesis tests*

Estimating parameters

- Parametric data (data consisting of parameters)

Hypothesis testing

- Non-parametric data (no parameters)

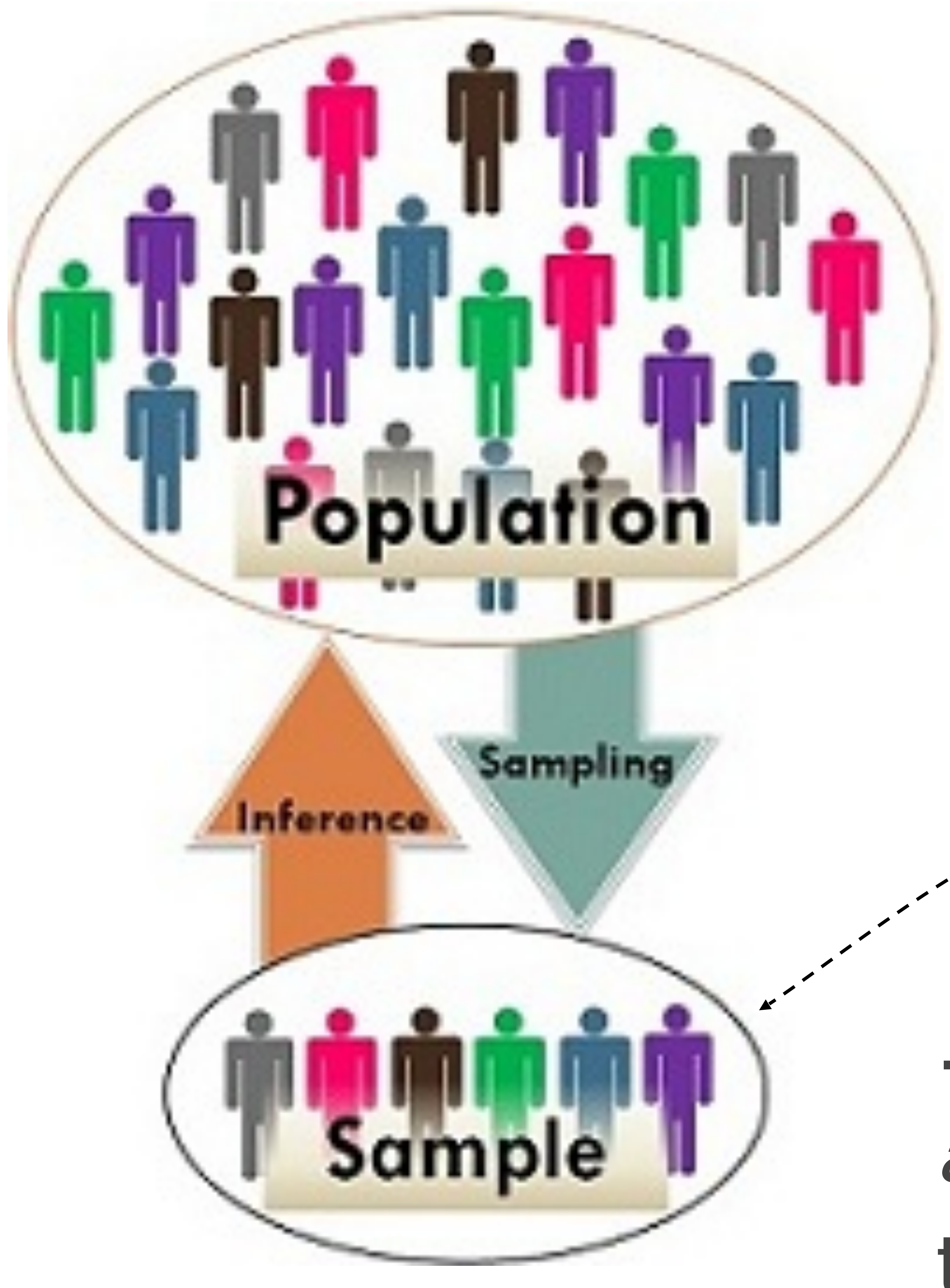
Statistic

“*A quantity computed from a sample*”

Source: dictionary.com

Populations & Samples

We want to learn something about this..



Our <u>population</u>: *all* Neurons in the motor cortex

Our <u>sample</u>: LFP ~ 1-10k neurons

....but we can only *actually* collect data from this

statistic

"A quantity computed from a sample"

For our YouTube analysis, we could take a random sample of comments from YouTube and calculate the following statistic: *the number of positive and the number of negative words in each review*.

Best sampling practices:

- Always think about what your population is
- Collect data from a sample that is representative of your population
- If you have no choice but to work with a dataset that is not collected randomly and is biased, be careful not to generalize your results to the entire population

You'd want to be sure you sample randomly across *all* YouTube comments, making sure not to get more comments from one genre over another, or one location over another, etc.

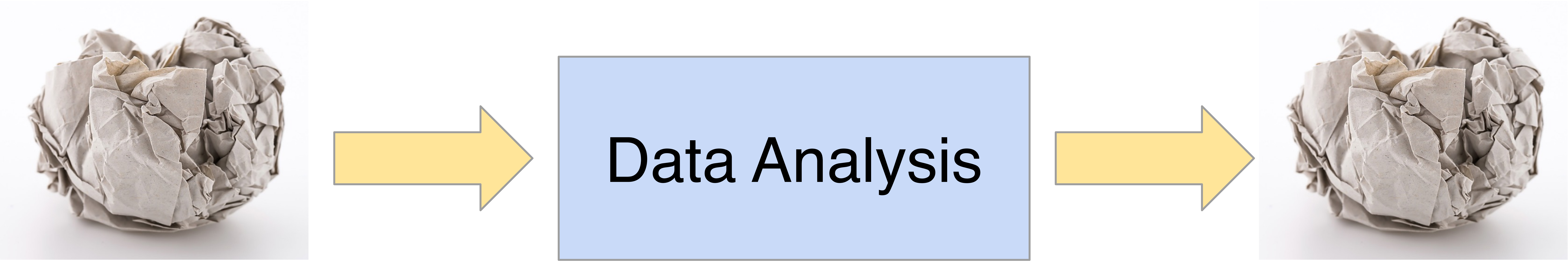
Examples of bad sampling:

- Surveying subscribers of a Marvel movie magazine for research on Americans’ attitudes toward DC movies
- Randomly sampling Facebook users for what TV shows people like

To understand *all* YouTube comments, you wouldn’t just want to sample from one YouTube channel, or videos in a single language.

It's *always* worth spending time at the beginning of a project to determine whether or not the data you have are garbage. Be certain they are actually able to help you answer the question you're interested in.

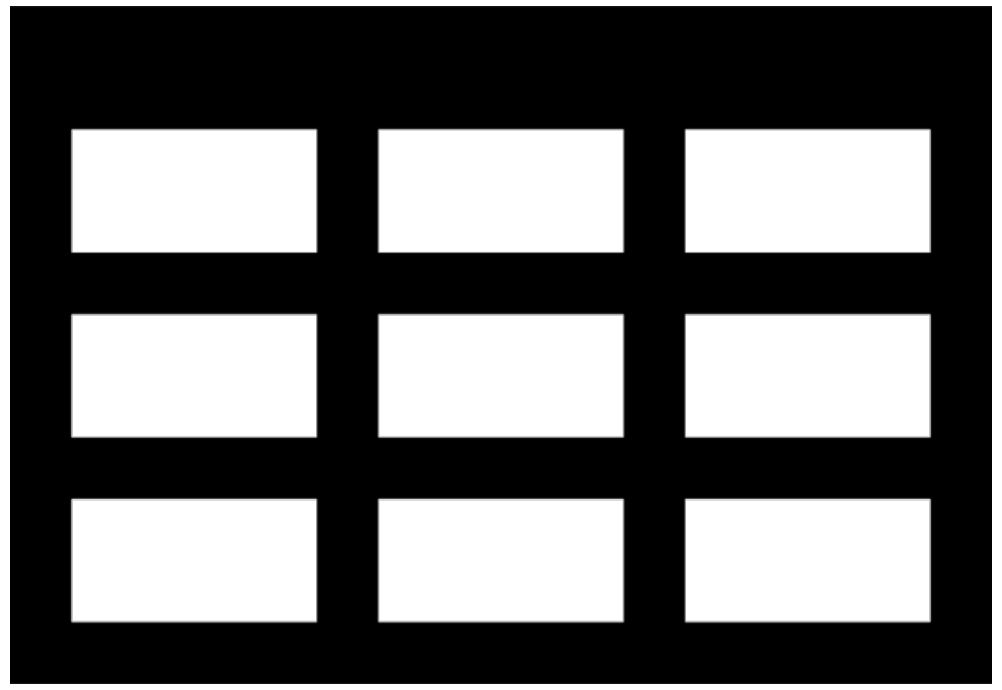
GIGO : Garbage In. Garbage Out.



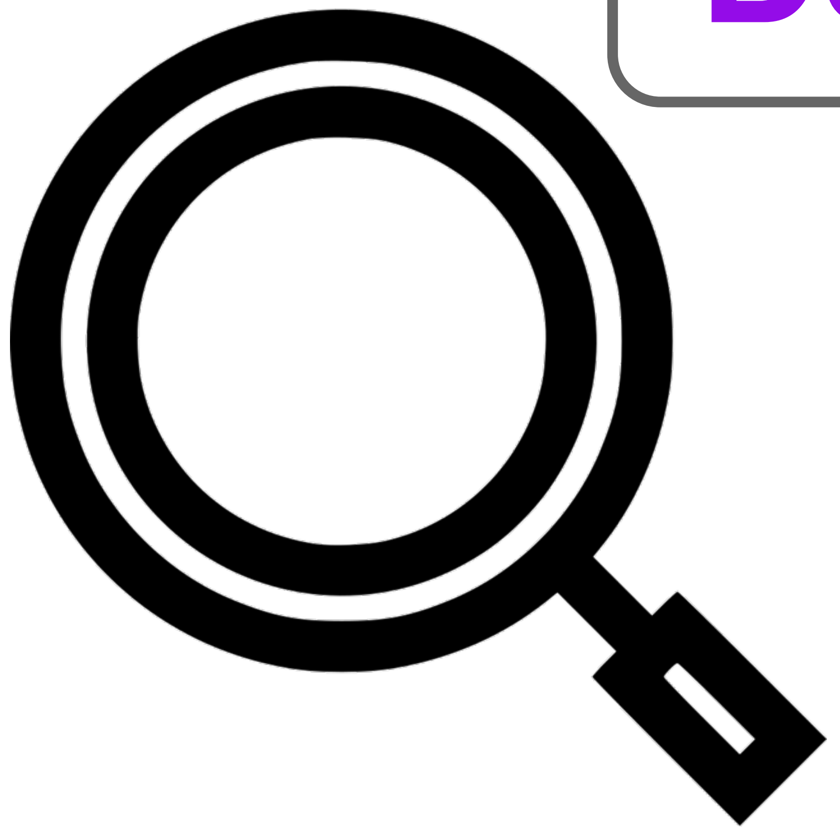
For survey data I collect from you all, which of the following best describes the population I could generalize findings back to.

- **A** Undergraduates
- **B** Undergraduates in the US
- **C** Undergraduates at UCSD
- **D** Students aged 18-25
- **E** UCSD COGS138 students

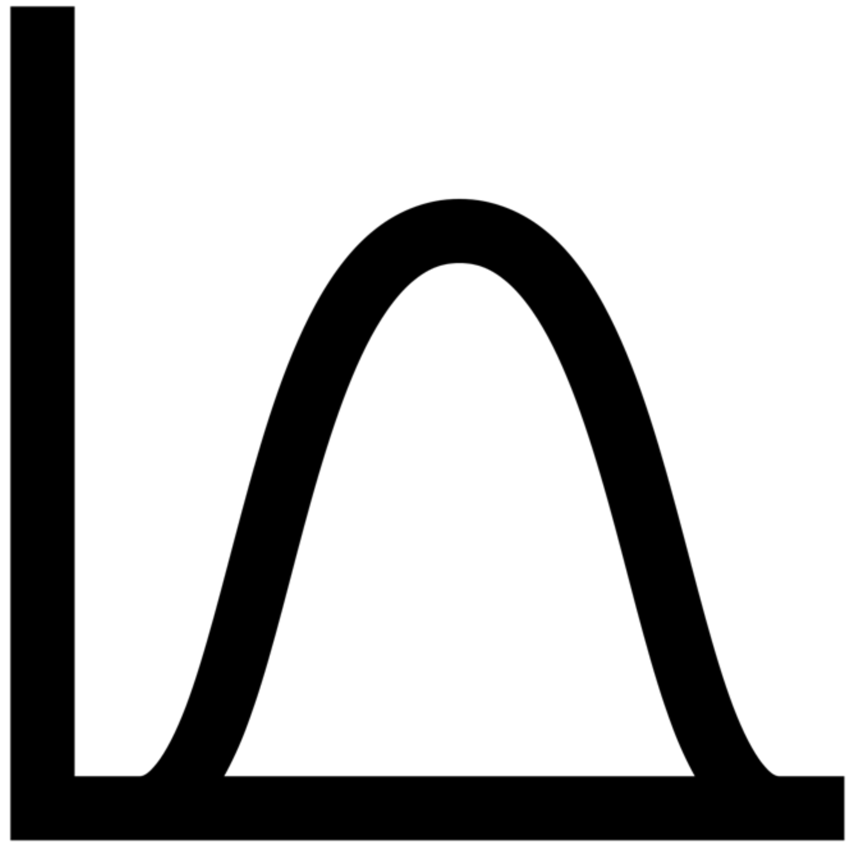
Descriptive Analysis



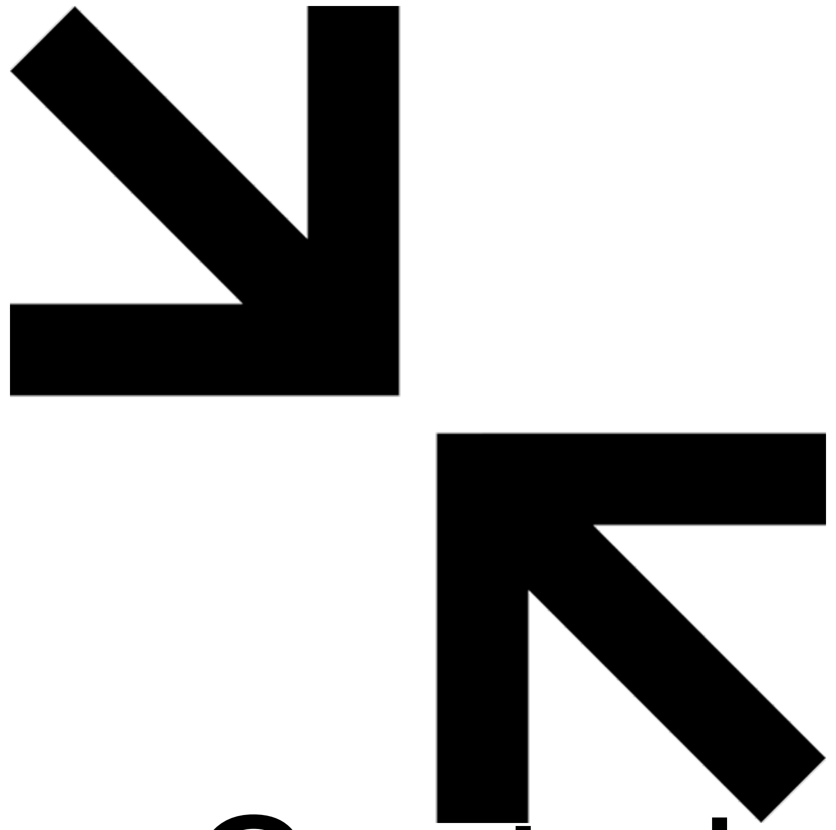
Size



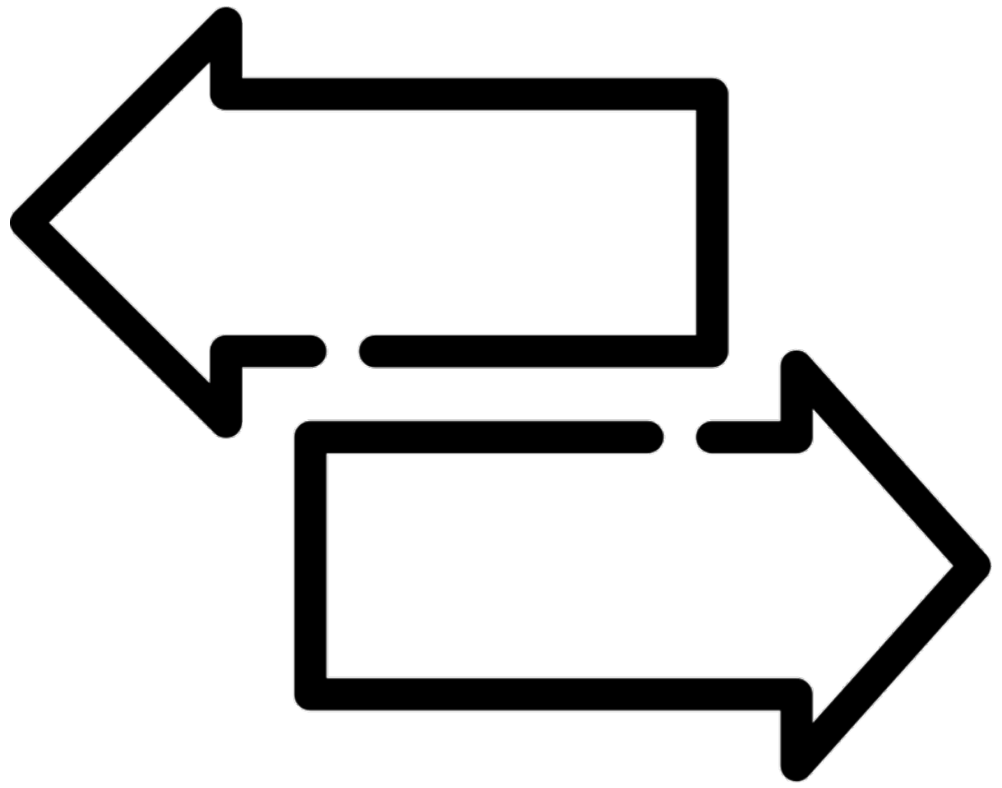
Missingness



Shape

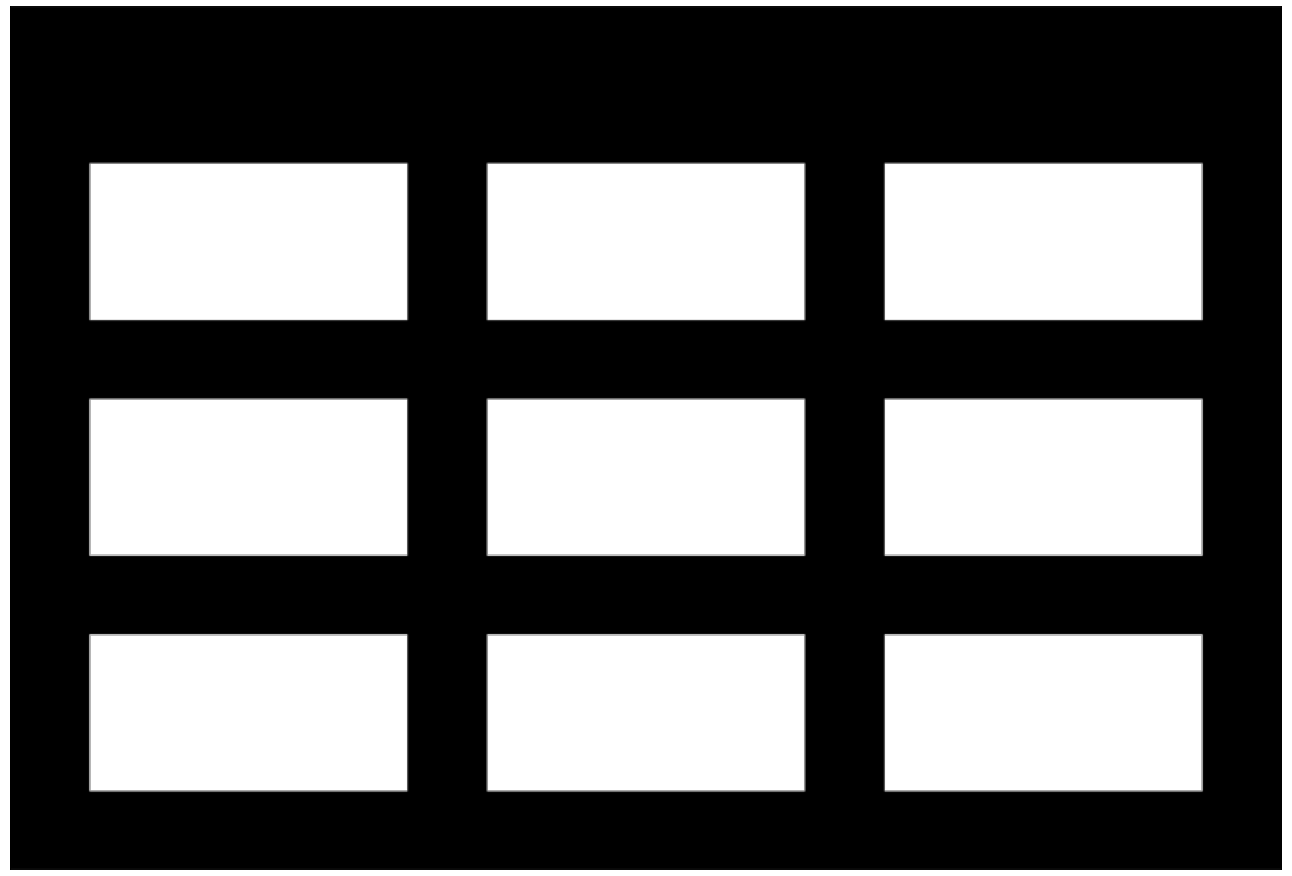


Central Tendency



Variability

Descriptive



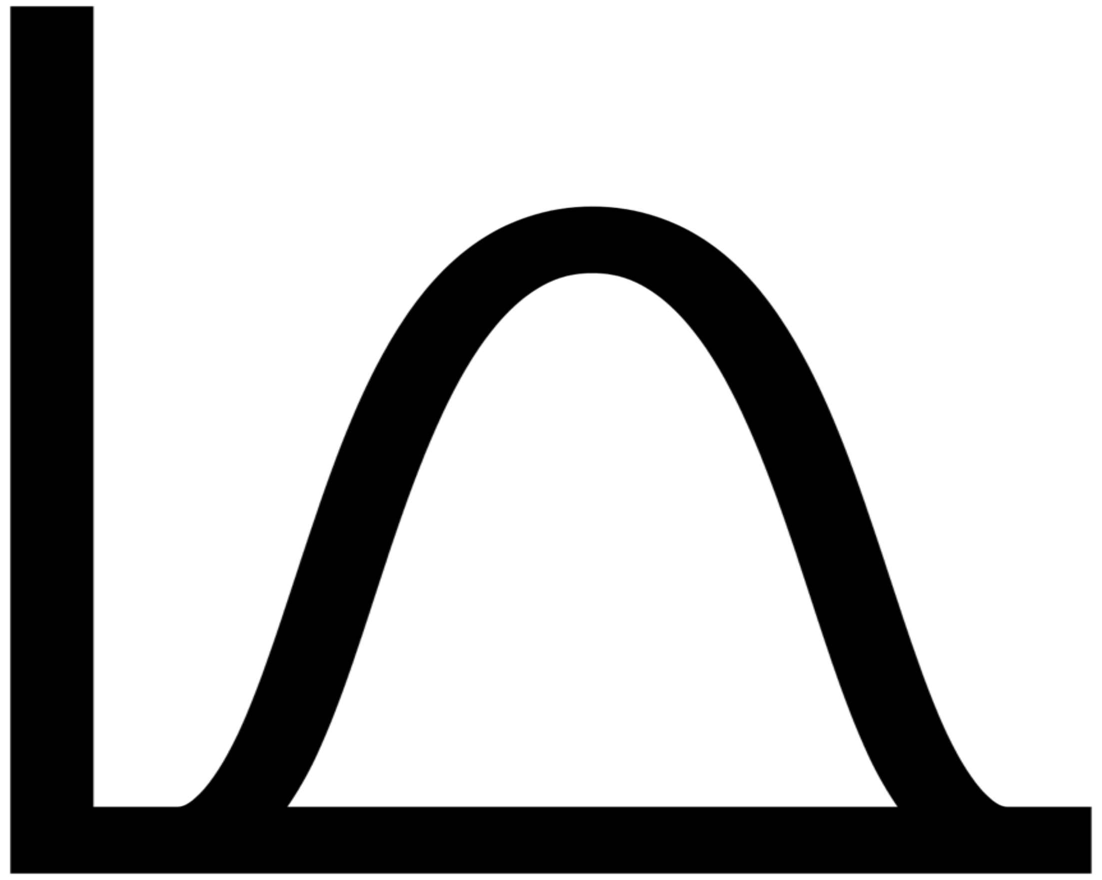
Size

How many observations (rows) and variables (columns) you have is an important first step. You should always be aware of the size of your dataset .

Descriptive

Missingness

It’s critical to know how many observations have missing data for variables of interest in your data. Knowing *why* their missing is also important.



Shape

Descriptive

It’s critical to know the distribution of the variables in your dataset. Certain statistical approaches can only be used with certain distributions.

Descriptive

Central Tendency

Knowing the mean, median, and/or mode can help you get an idea of what a typical value is for your variable(s) of interest

Descriptive

Variability

The central tendency tells you part of the story. The variability in the values in your observation helps fill in the rest.

Which of the following is NOT something accomplished by a descriptive analysis?

A Describes typical values in your dataset

B Determines the size of your dataset

C Establishes causal relationships between variables

D Identifies missing data

E Determines how variable values in your dataset are

Descriptive Statistics & Summary

- We look for the summary, the relevant features of the data to the study
- Use statistics to express them

Descriptive

Descriptive Analyses are often included as “Table 1” in academic publications

Table 1. Baseline Characteristics of the Patients.*

Characteristic	Ranibizumab Monthly (N=301)	Bevacizumab Monthly (N=286)	Ranibizumab as Needed (N=298)	Bevacizumab as Needed (N=300)
Age — no. (%)				
50–59 yr	2 (0.7)	1 (0.3)	6 (2.0)	2 (0.7)
60–69 yr	33 (11.0)	28 (9.8)	31 (10.4)	34 (11.3)
70–79 yr	102 (33.9)	84 (29.4)	115 (38.6)	103 (34.3)
80–89 yr	142 (47.2)	150 (52.4)	126 (42.3)	142 (47.3)
≥90 yr	22 (7.3)	23 (8.0)	20 (6.7)	19 (6.3)
Mean — yr	79.2±7.4	80.1±7.3	78.4±7.8	79.3±7.6
Sex — no. (%)				
Female	183 (60.8)	180 (62.9)	185 (62.1)	184 (61.3)
Male	118 (39.2)	106 (37.1)	113 (37.9)	116 (38.7)
Race — no. (%)†				
White	297 (98.7)	281 (98.3)	296 (99.3)	294 (98.0)
Other	4 (1.3)	5 (1.7)	2 (0.7)	6 (2.0)
History of myocardial infarction — no. (%)	34 (11.3)	40 (14.0)	30 (10.1)	36 (12.0)
History of stroke — no. (%)	14 (4.7)	18 (6.3)	22 (7.4)	16 (5.3)
History of transient ischemic attack — no. (%)	12 (4.0)	25 (8.7)	12 (4.0)	19 (6.3)
Blood pressure — mm Hg				
Systolic	134±18	135±19	136±17	135±17
Diastolic	75±10	75±10	76±9	75±10
Visual-acuity score and Snellen equivalent				
68–82 letters, 20/25–40 — no. (%)	111 (36.9)	94 (32.9)	116 (38.9)	103 (34.3)
53–67 letters, 20/50–80 — no. (%)	98 (32.6)	118 (41.3)	108 (36.2)	119 (39.7)
38–52 letters, 20/100–160 — no. (%)	67 (22.3)	53 (18.5)	58 (19.5)	58 (19.3)
23–37 letters, 20/200–320 — no. (%)	25 (8.3)	21 (7.3)	16 (5.4)	20 (6.7)
Mean score	60.1±14.3	60.2±13.1	61.5±13.2	60.4±13.4
Total thickness at fovea — μm‡	458±184	463±196	458±193	461±175
Retinal thickness plus subfoveal-fluid thickness at fovea — μm	251±122	254±121	247±122	252±115
Foveal center involvement — no. (%)				
Choroidal neovascularization	176 (58.5)	153 (53.5)	176 (59.1)	183 (61.0)
Fluid	85 (28.2)	81 (28.3)	77 (25.8)	72 (24.0)
Hemorrhage	20 (6.6)	24 (8.4)	24 (8.1)	25 (8.3)
Other	18 (6.0)	20 (7.0)	15 (5.0)	18 (6.0)
No choroidal neovascularization or not possible to grade	2 (0.7)	8 (2.8)	6 (2.0)	2 (0.7)

* Plus–minus values are means ±SD.
† Race was self-reported.
‡ Total thickness at the fovea includes the retina, subretinal fluid, choroidal neovascularization, and retinal pigment epithelial elevation.

https://www.nejm.org/doi/full/10.1056/nejmoa1102673

Descriptive

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Size

Shape

Central tendency

variability

Zooming in on this we see variables stratified by Age, Sex, and Race

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Descriptive

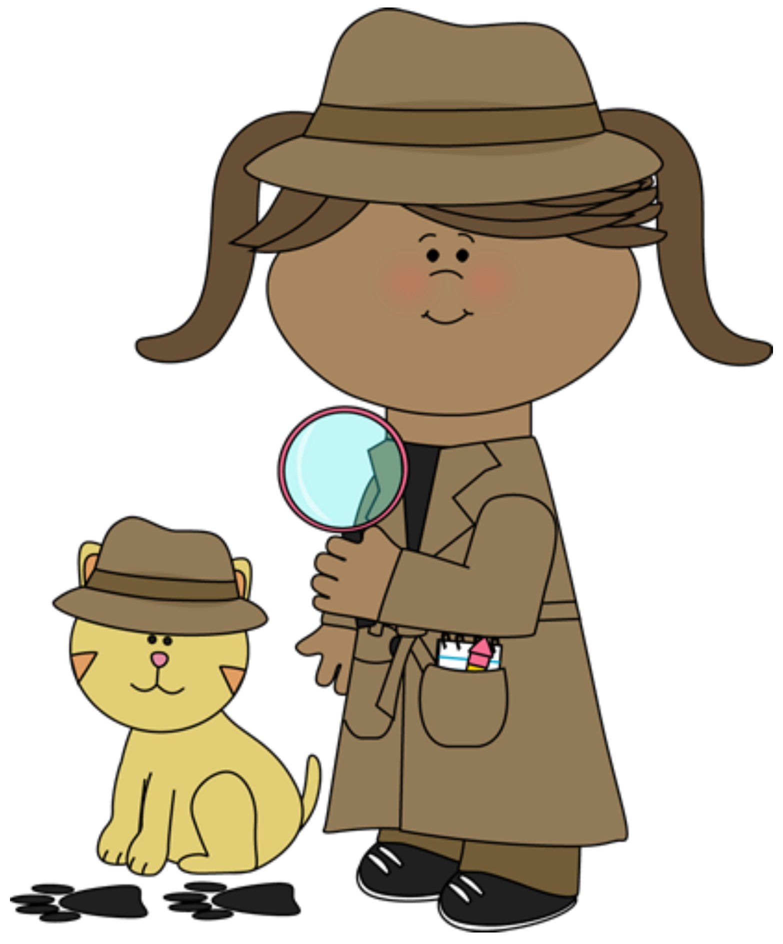
Descriptive Statistics & Summary

Calculating descriptive statistics, understanding what they tell you about your data, and reporting them are critical steps in every analysis.

Exploratory

Exploratory: The goal is to find unknown relationships between the variables you have measured in your data set. Exploratory analysis is open ended and designed to verify expected or find unexpected relationships between measurements.

Exploratory



Exploratory Data Analysis (EDA)
detective work answering the question:
"*What can the data tell us?*"

Why EDA?

Exploratory

- Understand data properties
- Discover Patterns
- Generate & Frame Hypothesis
- Suggest modeling strategies
- Check assumptions (sanity checks)
- Communicate results (present the data)

…..and if you don't, you'll regret it

Exploratory

You must always explore your data

The dataset

You

https://en.wikipedia.org/wiki/Blind_men_and_an_elephant#/media/File:Blind_monks_examining_an_elephant.jpg

Exploratory

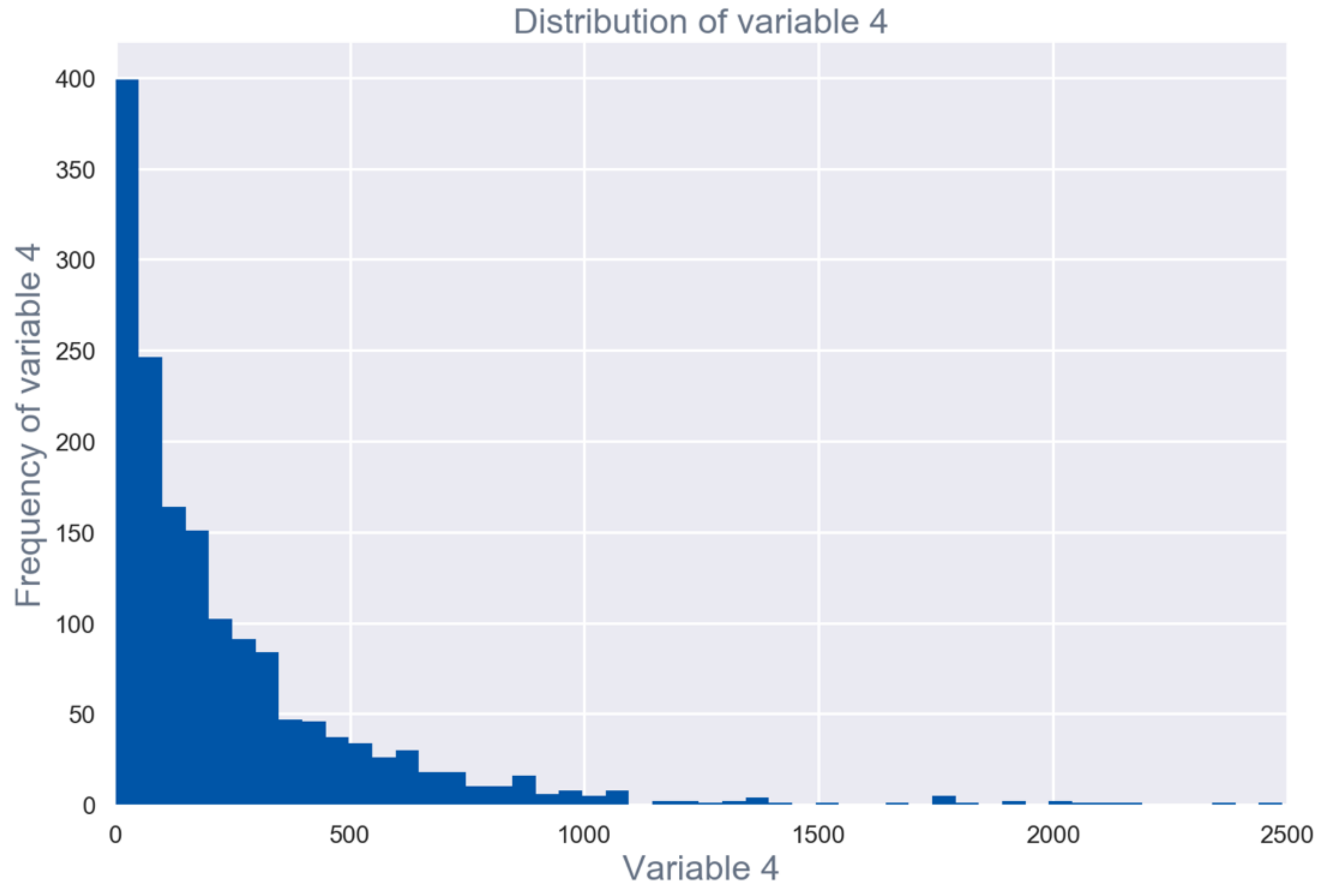
The general principles of exploratory analysis:

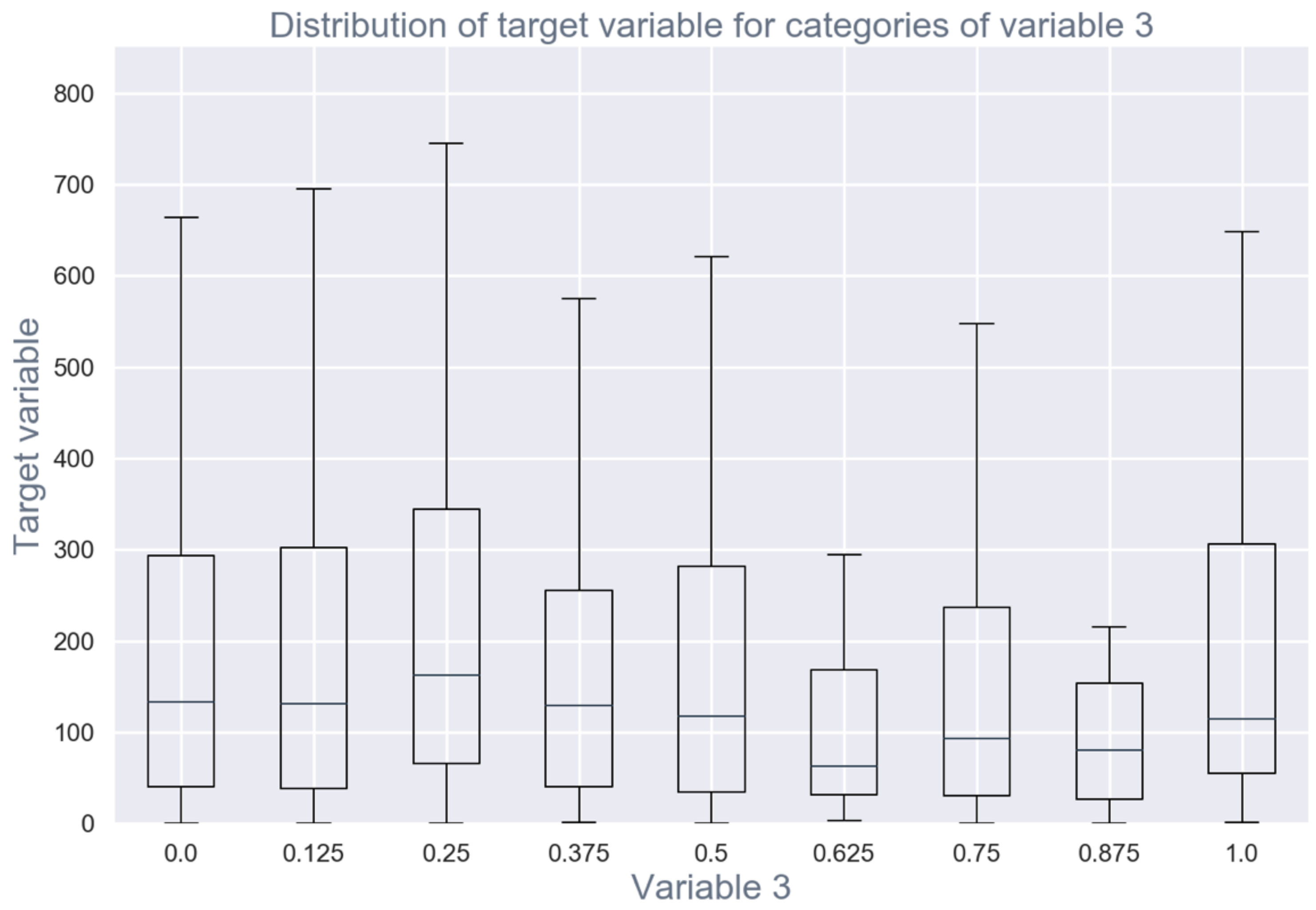
- Look for missing values
- Look for outlier values
- Calculate numerical summaries
- Generate plots to explore relationships
- Use tables to explore relationships
- If necessary, transform variables

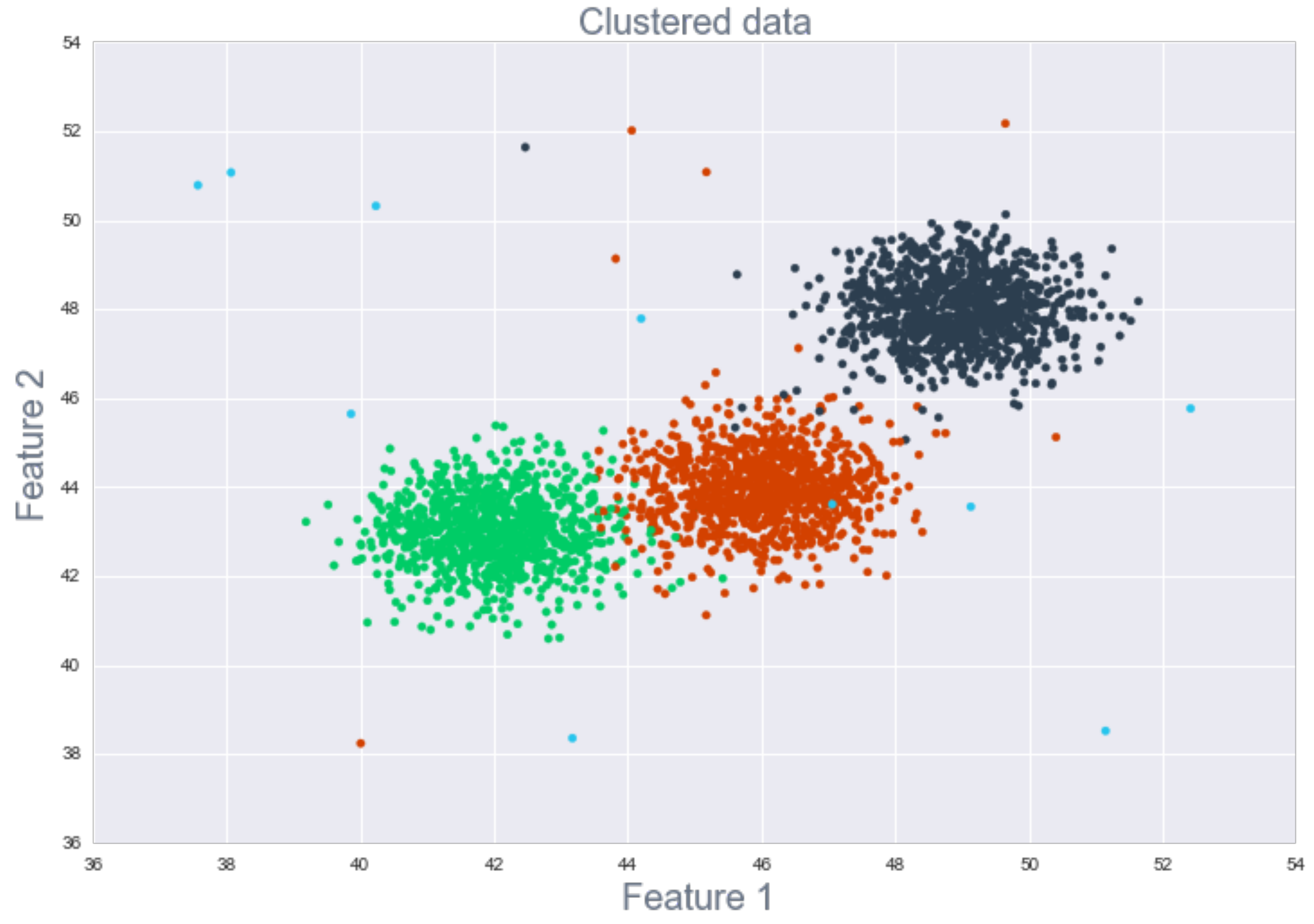
EDA Approaches to “Get a Feel for the Data”

Exploratory

Understanding the relationship between variables in your dataset







Univariate

understanding a single variable

i.e.: histogram, densityplot, barplot

Bivariate

understanding relationship between 2 variables

i.e.: boxplot, scatterplot, grouped barplot, boxplot

Dimensionality Reduction

projecting high-D data into a lower-D space

i.e.: PCA, ICA, Clustering

Image source: https://www.svds.com/value-exploratory-data-analysis/

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Geospatial Statistics
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