Measurements of data representation:

• Nominal – categorical. • Ordinal – ranked

• Interval – difference is meaningful.

• Ratio – ratio with a unit

Privacy and Sensitive Data: Information that is protected against unwarranted disclosure

• Health-related data. • Genetic data, biometric data

• Personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, sexual orientation

Data "Born Digital": Originally recorded or created in digital form.

Data lifecycle: Define Questions -> Collect/find Data -> Store Data -> Extract Data -> Pre-process Data -> Analyze Data -> Present Results -> Publish Data

Collect/find Data:

• **Frequency:** Interval of collection. • **Granularity:** Range for each group.

• **Cost:** Takes many forms: money, time, storage, processing, effort, etc.

• **Utility**

Extract Data: Data queries to extract useful subsets or slices of the data.

Preprocessing: Reformatting, Conversion, Cleaning, Imputation, Integration, Feature generation, Feature construction, and Feature selection.

Possible Pre-processing Steps:

• **Data reformatting:** changing the format or encoding of the data: Changing an image from JPG to PDF

• **Data conversion:** changing the unit of measurement or representation: Average temperatures in different countries, data is in C and F

• **Data cleaning:** detecting and correcting errors: Temperature time series: 70, 68...

• **Data imputation:** hypothesizing missing values: Temperature time series: 9am 50, 10am --, 11am 60.

• **Data integration:** mapping objects across datasets, merging them: Use data from two separate social networks

Programming language: High-level Programming Language -> Compiler -> Low-level Programming Language

Compiled vs Interpreted languages.

Algorithms: An algorithm is a mechanical procedure that describes how to carry out an explanation of some data the logic (like a recipe). Algorithm describes a process and rules to execute the process with a machine.

Algorithms vs Programs: An algorithm is a mechanical procedure that describes how to carry out a computation on some data (the logic), like a recipe. Programmers design algorithms and then turn them into programs that can be executed.

Computational Workflows: Workflow is represented as a graph of connected nodes.

• Nodes represent programs and data (alternatively)

• Links represent how data flows from program to program (output to input).

• No user interaction during execution. • No cycles/loops or iterations allowed !!!!!

Repeatability: Same lab, same data, same Analysis.

Reproducibility: Different lab, same data, same Analysis.

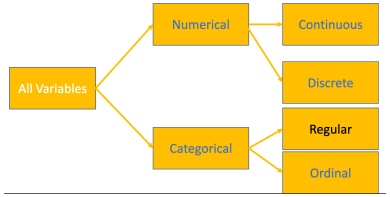
Replication: Different lab, different data, same method (re-run study).

Provenance: Documenting How Results Are Obtained. what workflow was used, what its components were, what the input data was, and what values were assigned to the parameters.

Observational Studies: Collect data in a way that does not directly interfere with how the data arise (observe). Only allows to associate variables.

Experiments: Randomly assign subject to treatment. Establish causal connections.

Types of variables:



Independent Variable: Variable that you think affects the other variable. **Also called**: Exposure variable, Control variable, Explanatory variable, Manipulated variable. Manipulated in an experiment. Measured in Observation.

Dependent Variable: The outcome variable (you think Inferential Tests and Statistical Significance it has an effect on). **Also called**: Outcome variable, Controlled variable, Explained variable, Response variable.

Confounding Variables: Variables that affect both the independent and dependent variable, and that make it seem like there is a relationship between them.

Dependent Variable: The outcome variable (you think it has an effect on). Measured in an experiment and observation.

	Observational	Experimental
IV	Measure	Manipulate
DV	Measure	Measure

Correlation Does Not Imply Causation: directionality problem & third-variable problem.

Observational vs. Experimental:

Observational research: (1) Important, "hard to manipulate" real-life outcomes. **(2)** Could not ethically or practically manipulate.

Experimental research: (1) Make causal claims**. (2)** Can manipulate cleanly

Measures of center: mean, median, mode.

Measures of spread: variance, standard deviation, range, inter-quartile range.

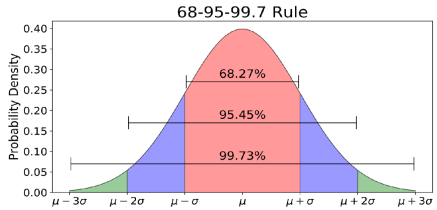
Law of large numbers: In any probability space the average of the results obtained from a large number of trials converge to the expected value.

Independence: Two processes are independent if knowing the outcome of one provides no useful information about the outcome of the other.

Conditional Probability:

$$P(A|B) = \frac{P(AB)}{P(B)}$$

68-95-99.7% rule:



Descriptive vs Inferential Statistics:

• **Descriptive statistics:** Summarizes data.

• **Inferential Statistics:** Inferences from the data.

Inferential Tests and Statistical Significance: If p is less than designated cutoff, then we say the result is statistically significant. **Other way of representing p value:** incorrectly rejecting the null, false positive, type I error.

Effect Size: is a measure of the strength of the relationship between two variables. Most commonly reported effect sizes is Cohen's d.

$$\textbf{Effect Size} = \begin{cases} \textbf{\textit{Small}}\ effect, & d = 0.2, \\ \textbf{\textit{Medium}}\ effect, & d = 0.5 \\ \textbf{\textit{Large}}\ effect, & d > 0.8 \end{cases}$$

Types of statistical tests:

	Continuous predictor	Categorical predictor
Continuous predictor	correlation or regression	t-test or ANOVA
Categorical predictor	Logistical regression	Chi-square test or loglinear.

Independent Samples t-test: Compares two independent groups.

Paired-Samples t-test: Compares one group that has been tested twice, Before and after; under two different conditions.

One-way ANOVA: Used when the predictor variable has more

than two levels.

Chi-Square: Used to analyze categorical (count or proportion) data.

Correlation coefficient: Used to represent the relationship between two continuous variables.

Statistical tests evaluate a null hypothesis: which states that there is NO relationship or effect (i.e., no difference between groups) Able to reject the null hypothesis if it is sufficiently unlikely (5/100 or .05) that your sample (and it's test statistic) came from this sampling distribution (where there is NO relationship or effect; i.e., no differences between groups)

Type I Errors: Rejecting a true null hypothesis.

• Decide the probability α in advance for a given test

• The standard cutoff is .05, meaning there is a 5% chance of a Type I Error Sampling distribution

Type II Errors: Failing to reject a false null hypothesis.

• Statistical power is equal to 1 – β.

• Measure of the sensitivity of the test (increases with N).

• Influenced by experimental design and the size of the effect.

• Impossible to know precisely in advance, but you can estimate.

"Fail to Reject" the Null Hypothesis: Remember, only trying to disprove the null. When we do not reject, this is not the same as accepting the null! Could be support for experiment hypothesis

Machine Learning algorithms discover the relationships between the
variables of a system (input, output and hidden) from direct samples/observations of the system.

Supervised learning (Classification) & Unsupervised learning (clustering)

Reinforcement learning: Learning through interaction with the environment by maximizing cumulative reward.

• **Discount factor** allows for calculating this for infinite horizon Markov Decision Processes.

Training of Decision Tree: **(1)** Start with the set of all instances in the
root node. **(2)** Select the attribute that splits the set best and create children nodes. **(3)** When a node has all instances in the same class, make it a leaf node. **(4)** Iterate until all nodes are leaves.

***k* of kNN**: **(1)** If k is too small, sensitive to noise points. **(2)** If k is too large, neighborhood may include points from other classes.

Advantage: Lazy learner. **Disadvantage:** Sensitive to Noise.

Linear classification Main Assumptions: **(1)** Linear weighted sum of attribute values. **(2)** Data is linearly separable. **(3)** Attributes are real valued.

What model to choose: Data scientists try different models, with different parameters, and check the accuracy to figure out which one works best for the
data at hand.

Overfitting: A model overfits the training data when it is very accurate with that data, and may not do so well with new test data.

Nonlinearity activation functions: Faster convergence.

• Hidden layers: Tanh, Sigmoid, RELU, GELU.

• Output layers: Sigmoid, Softmax.

Neural network training optimization does **not guarantee** reaching the global minimum (non-convex optimization).

Bias-variance tradeoff: Unfortunately, it is not always possible to minimize both variance and bias at **the same time**. In general, **bias** is reduced if we add more and more parameters to a model and make it more complex. However, **the more complex the model** becomes the more variance we introduce in the model. In its core, the problem alludes to over- and under- fitting.

• **Data: labeled instances**,: Training, Validation, Test

• **Training**

  • Estimate parameters on training set.

  • Tune hyperparameters on validation set.

  • Anything short of this yields over-optimistic claims.

• **Evaluation**

  • Ideally, the criteria used to train the classifier should be closely related to those used to evaluate the classifier.

• **Statistical issues**

  • Error bars: want realistic (conservative) estimates of accuracy.

Unseen test set provides an unbiased estimate of accuracy.

k-fold cross-validation: The available data is partitioned into k equal-size disjoint subsets. Use each subset as the test set and combine the rest k-1 subsets as the training set to learn a classifier.

Confusion Matrix

		Predicted class	
		Positive	Negative
True class	Positive	TP	FN
	Negative	FP	TN

$$Accuracy = \frac{TP + TN}{N}$$

$$Recall = Sensitivity = \frac{TP}{TP + FN}$$

$$Precision = \frac{TP}{TP + FP} = \frac{TN}{TN + FP}$$

F1-Score: It is hard to compare two classifiers using two measures. F1 score combines precision and recall into one measure.

$$F1 - Score = \frac{2Recall \times Precision}{Recall + Precision}$$

What affects the performance: **(1)** Large amounts of features for simple models (high dimensionality). **(2)** Missing feature values for instances (sparse data). **(3)** Model capacity. **(4)** Errors in feature values for instances. **(5)** Errors in the labels of training instances (noisy or weak labels). **(6)** Too few instances for a complex classification task. **(7)** Uneven availability of instances in classes.

Unsupervised Learning: Learning the structure of the data. For example: PCA and Clustering.

Syntax: Sentence structure, its constituents and morphological presentation of a word.

Semantics: Meaning of text. It's the fundamental take-away after you read a sentence.

Stop words removal: Common words with no or little value in helping with the task.

Tokenizing: Divide the sentences into words (or subwords).

Optional task-dependent steps: **(1)** Lowercase. **(2)** Removing stop words.

Text Parsing: Process of determining the syntactic structure of a text by analyzing its constituent words based on an underlying grammar (of the language).

Named entity recognition: Identify which components of a sentence are important for a task.

Typical applications of NLP: Text classification, Entity extraction, Question answering, Dialogue systems, Summarization, Information retrieval.

NLP in Finance: Use social media (e.g., Twitter) data to automatically measure public mood can be used rather than (expensive) traditional polls.

Sentiment analysis is the detection of attitudes: (1) Holder (source) of attitude. (2) Target (aspect) of attitude. (3) Type of attitude. (4) Text containing the attitude.

Automatic summarization: Reduce the amount of data (hence time) for other analysis tasks.

Topic modeling: Helps us identify "abstract" topics in documents.

Word embeddings: Compact representations (vectors) representing each word.

Vector space models of words: While learning these word representations, we are actually building a vector space in which all words reside with certain relationships between them.

BERT: Can give sentence and contextualized embedding.

Feature	Workflow systems	Electronic notebooks
Simple programming paradigm	✓	✗
Modular assembly	✓	✗
Composing heterogeneous codes	✓	✗
Abstraction	✓	✗
Data preparation steps	✓	✓
Data visualization steps	✓	✓
Documenting provenance	✓	✓ *(limited)*
Automatic processing of multiple inputs	✓	✗
Large scale processing	✓	✗
Facilitating communication across data science expertise areas	✓	✗