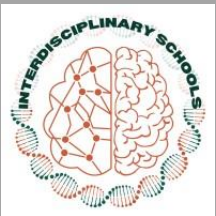


# Statistics in Electrophysiology

Babak.Aliyari.edu@gmail.com



<https://interdisciplinarieschools.com/>

*serendipity*



# serendipity

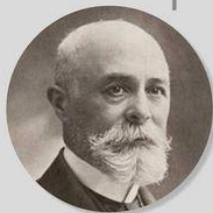
#NobelPrizeInPhysics



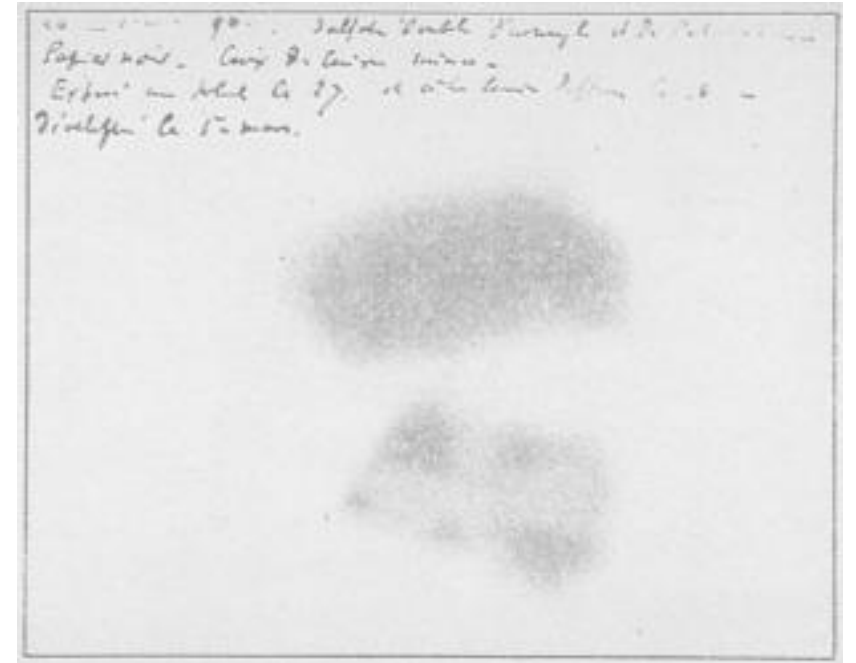
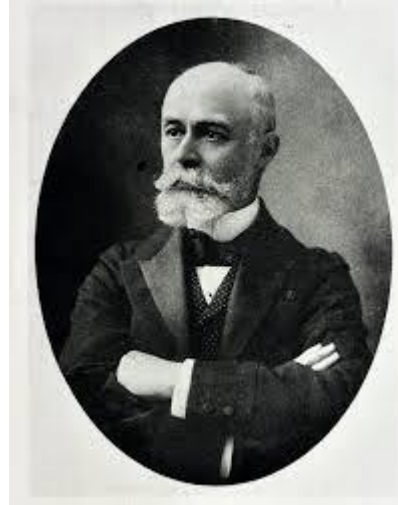
Nobel Prize in Physics  
1903

**Antoine Henri Becquerel**

"In recognition of the extraordinary services  
he has rendered by his discovery of  
spontaneous radioactivity"



**SYNAPSE**  
ACADEMY OF SCIENCE



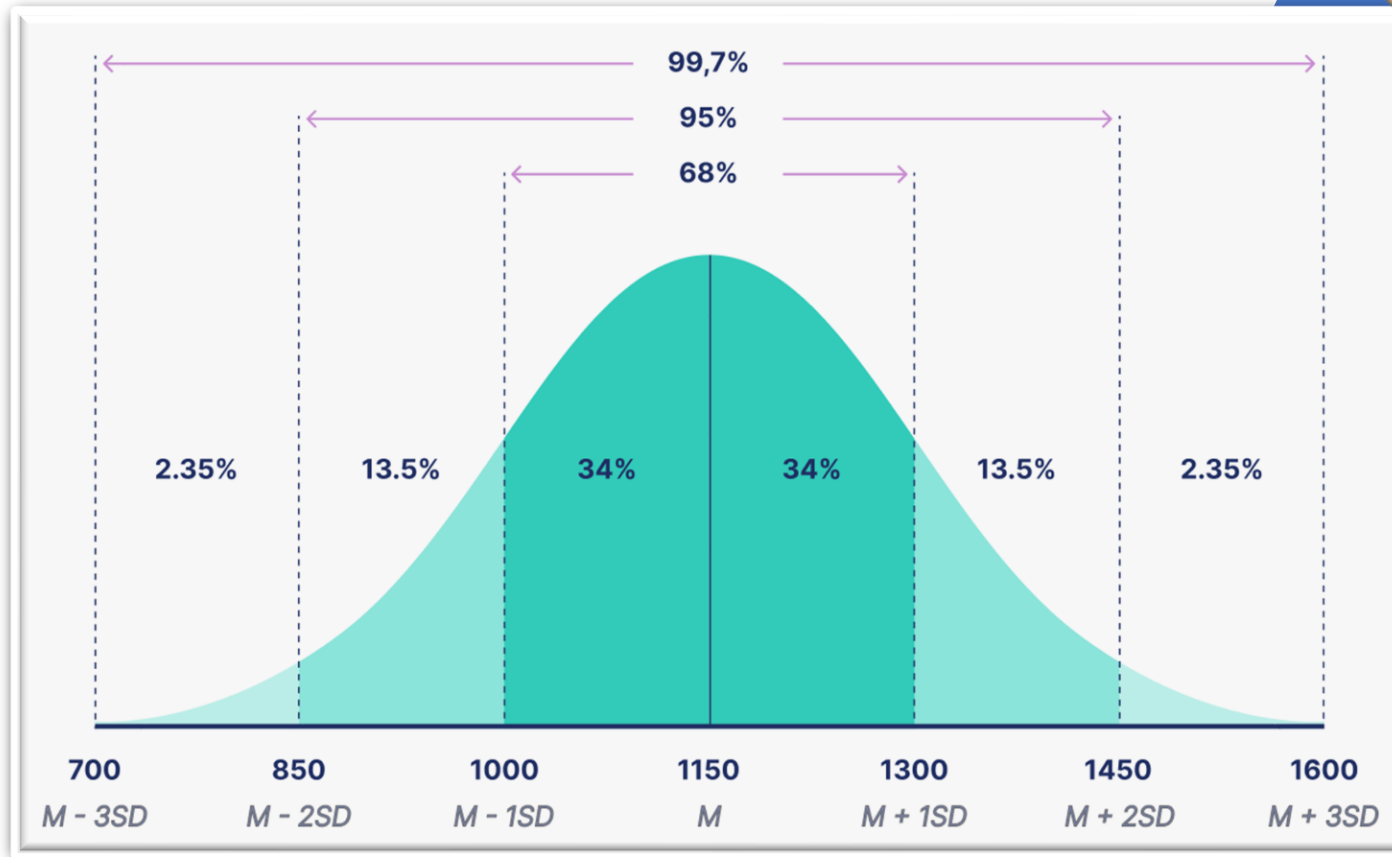
# Outliers...



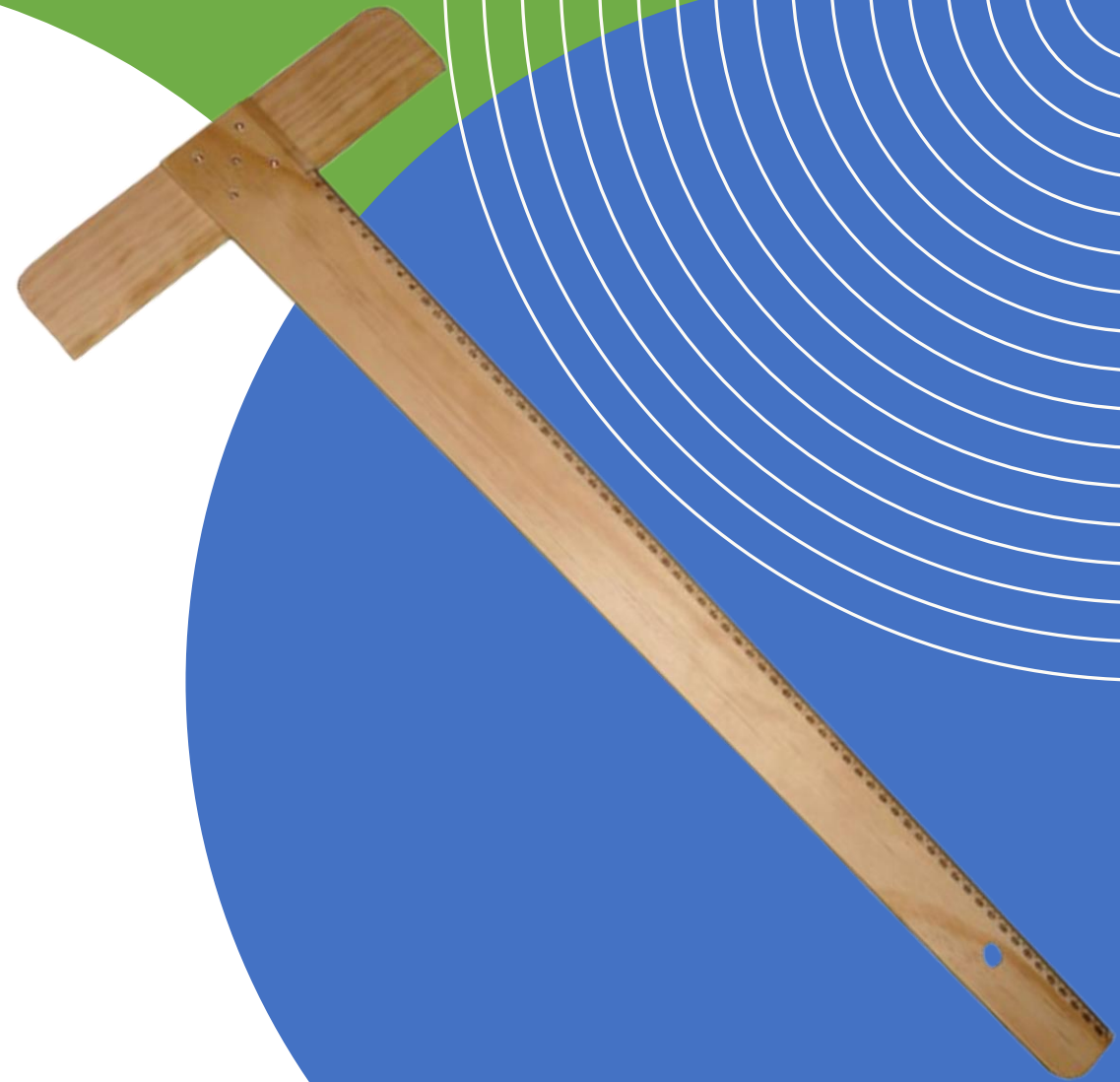
“An outlier is an observation that lies an **abnormal distance** from other values in a **random sample** from a population.”  
Douglas Hawkins



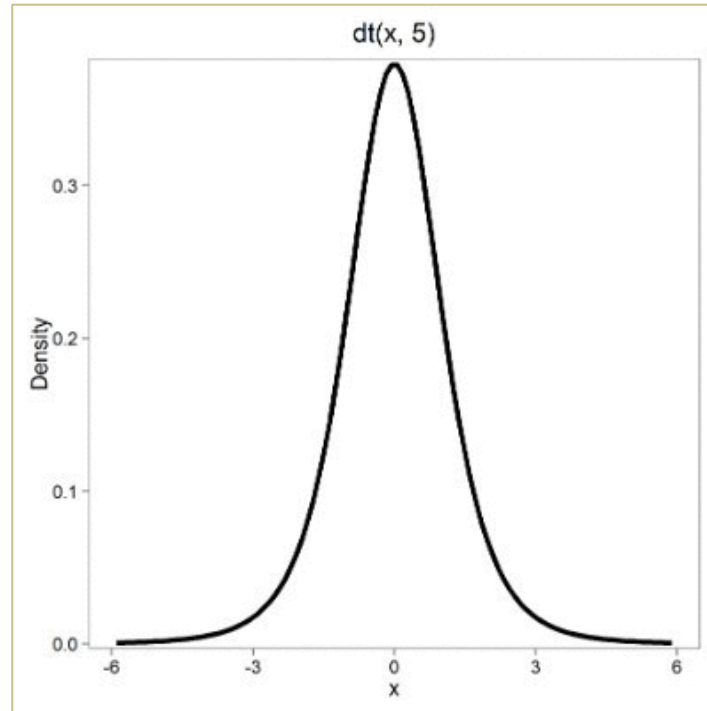
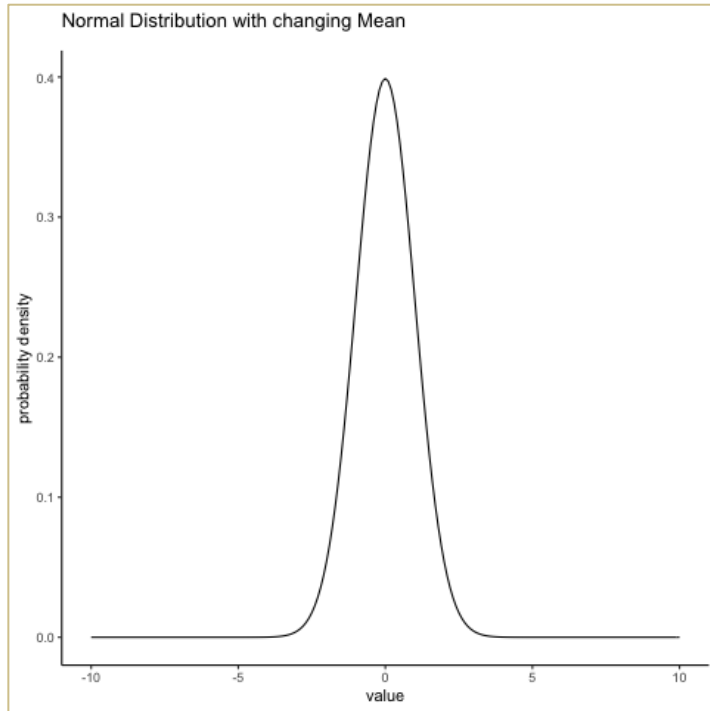
# Normal distribution



# Normal distribution



# Anatomy of normal distribution



$$y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x - \mu)^2}{2\sigma^2}}$$

$\mu$  = Mean

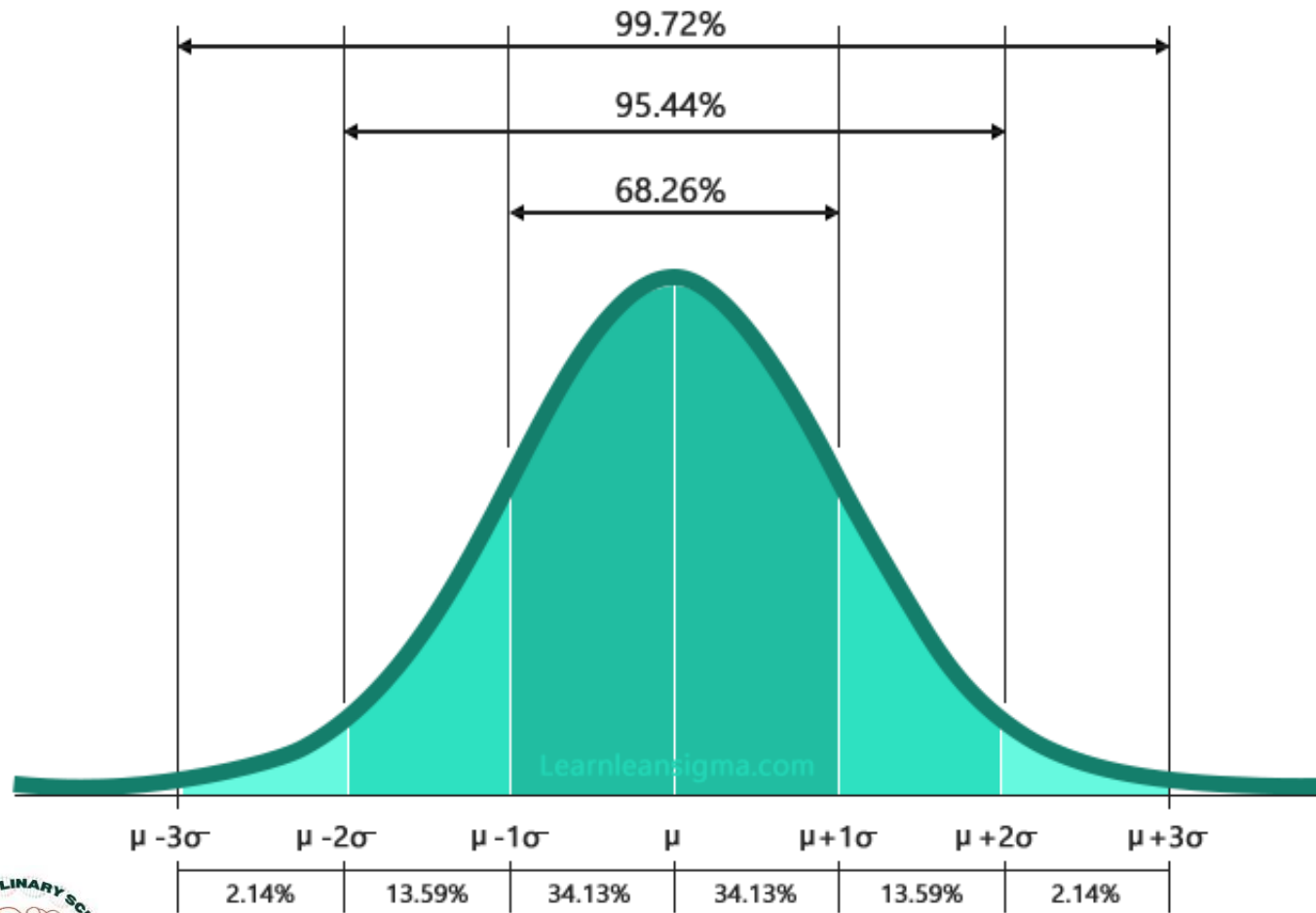
$\sigma$  = Standard Deviation

$\pi \approx 3.14159 \dots$

$e \approx 2.71828 \dots$



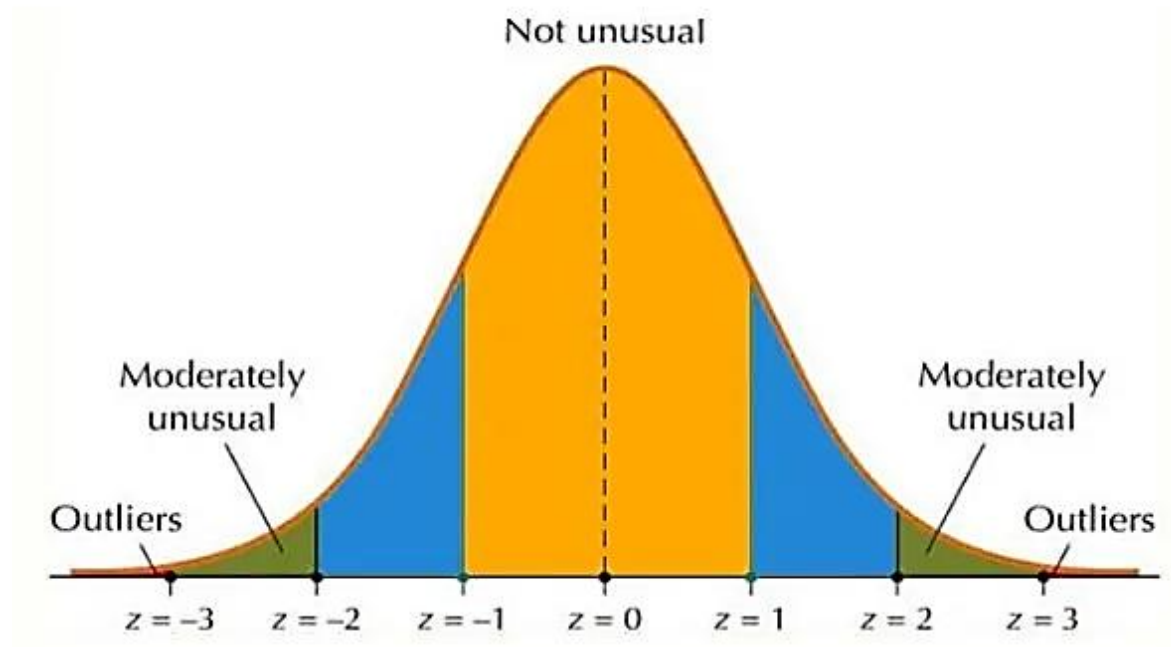
## normal distribution and Sigma





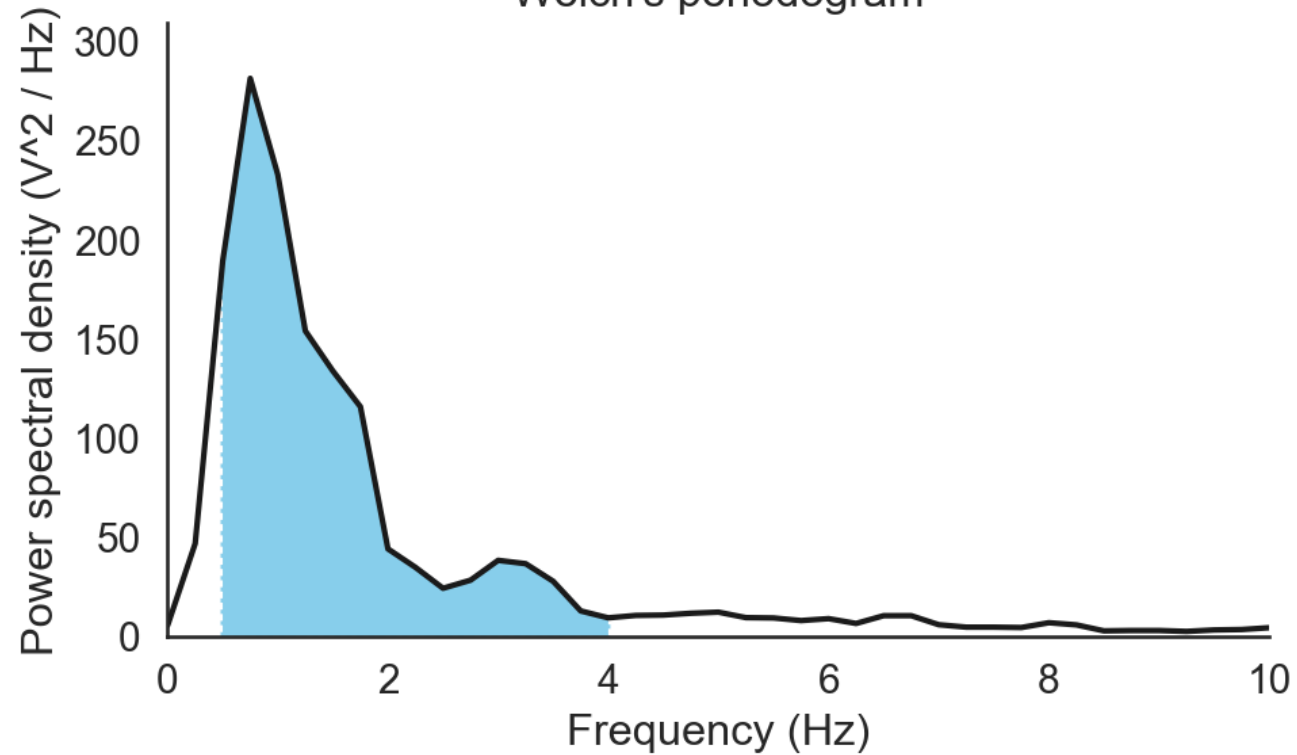
# Outliers Normal Distribution

9

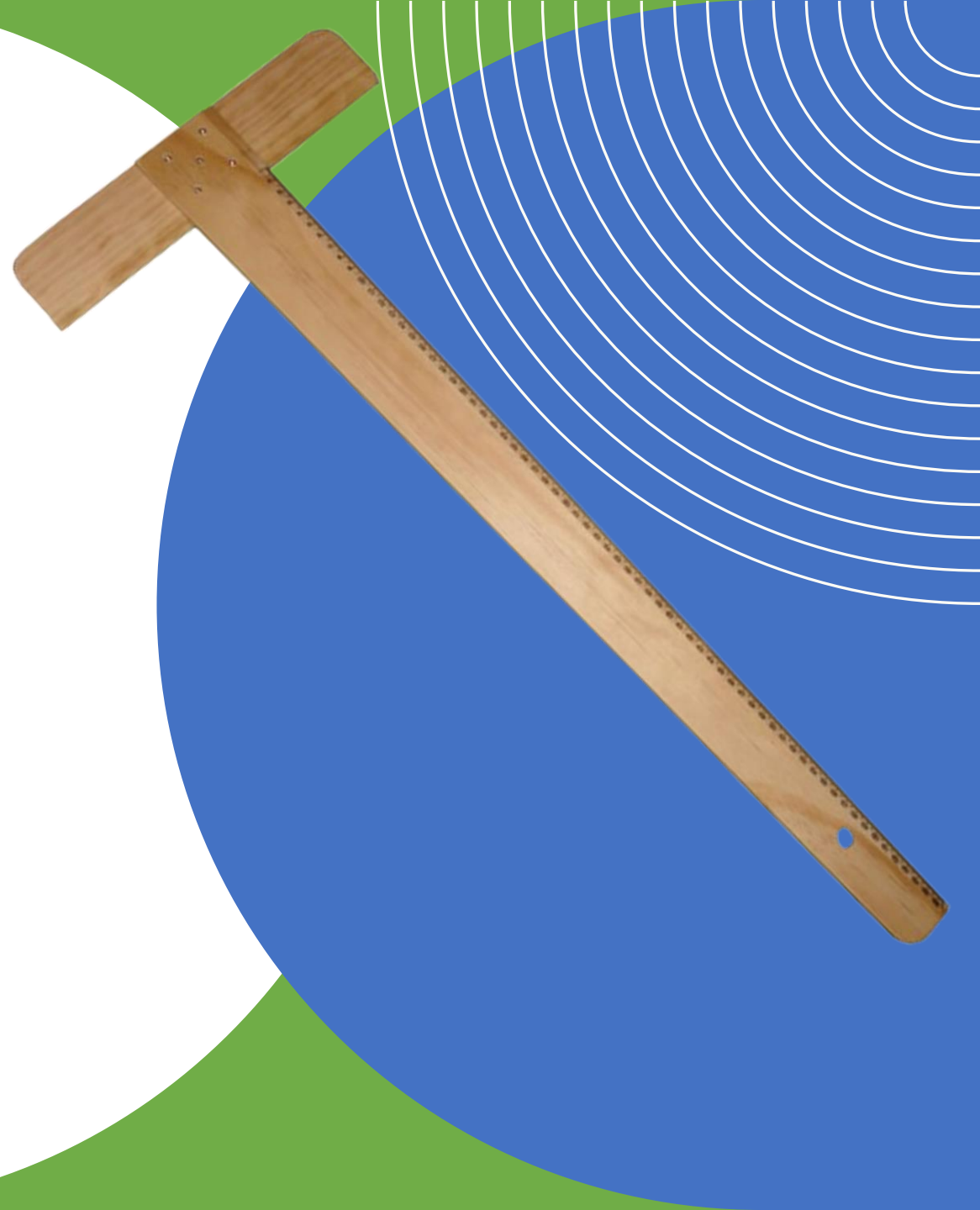
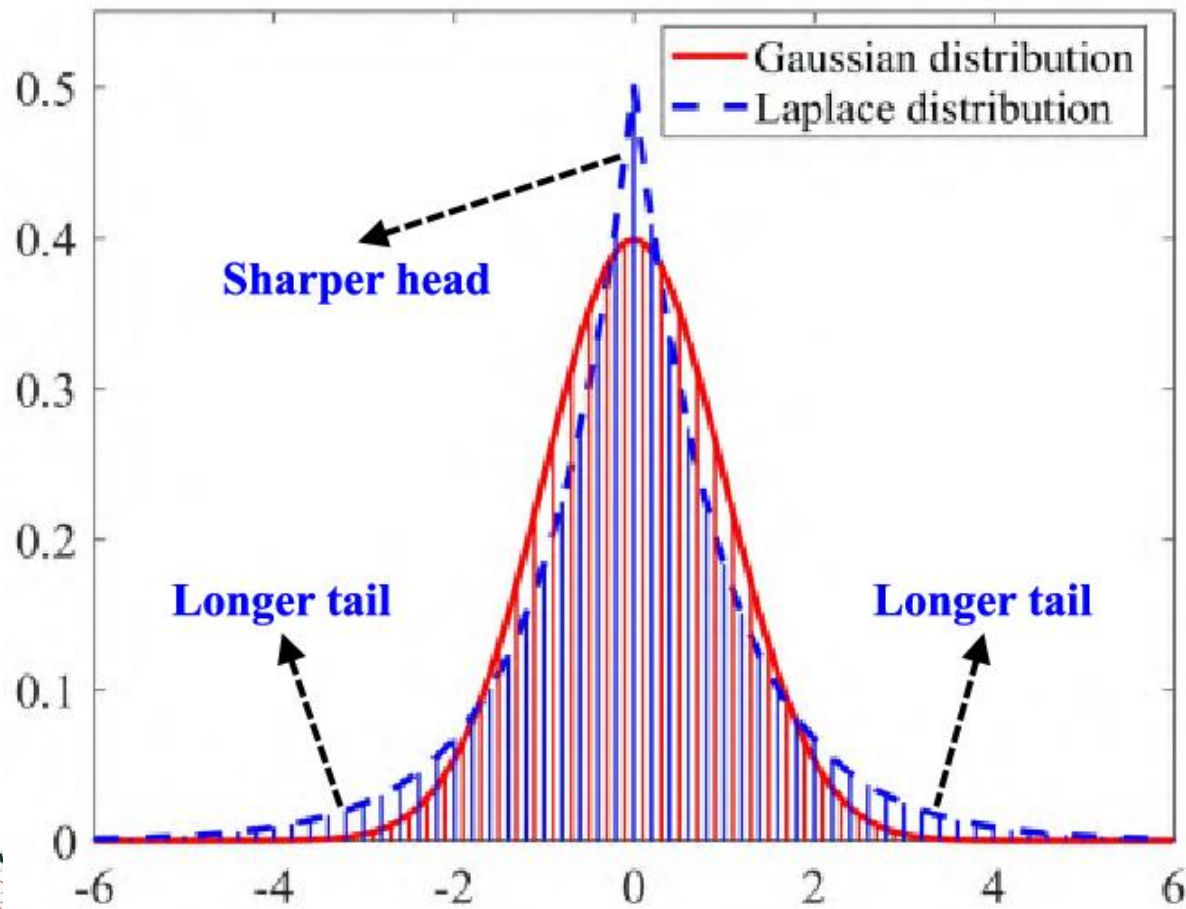


تمرین هفتگی:  
چرا نمودار زیر از توزیع نرمال پیروی نمی‌کند؟

Welch's periodogram



# Laplace distribution

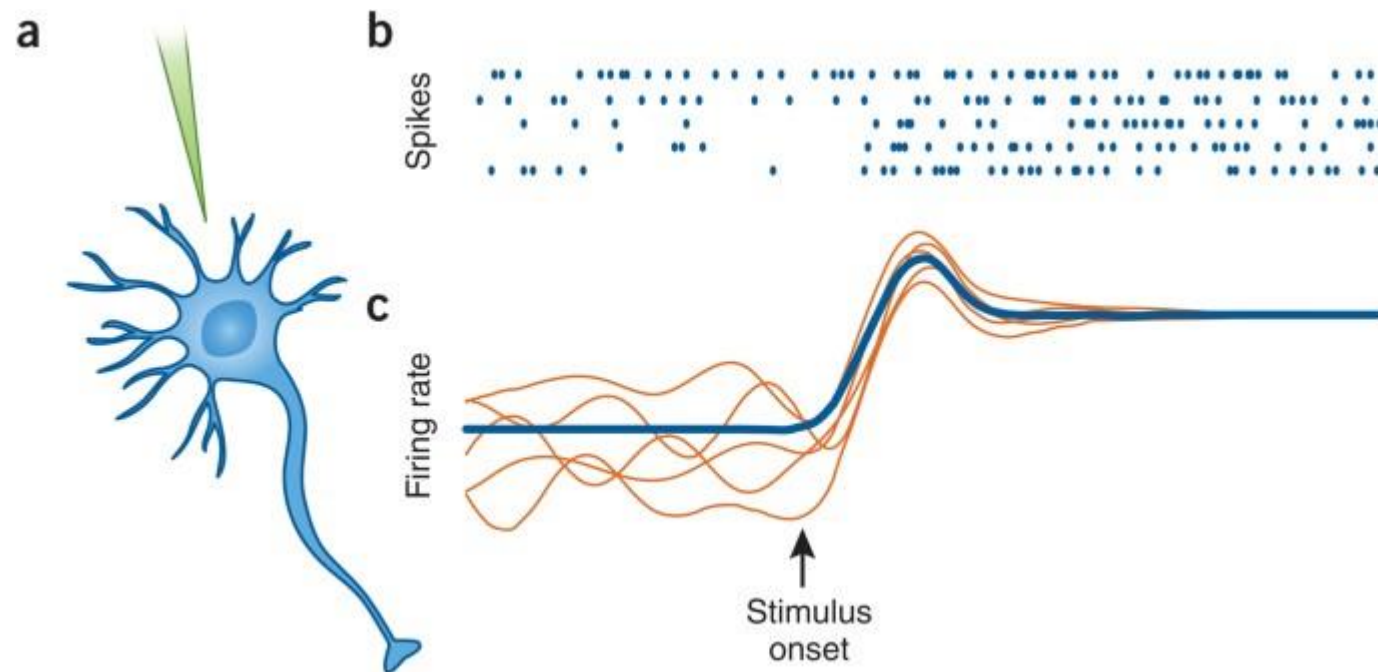


## When to Use the Laplace Distribution

1. Robust Statistics (Handling Outliers)
2. Modeling Phenomena with Heavy Tails
3. When we use median not mean
4. Regularization in Machine Learning (Lasso Regression)
5. Image and Signal Processing
6. Bayesian Statistics

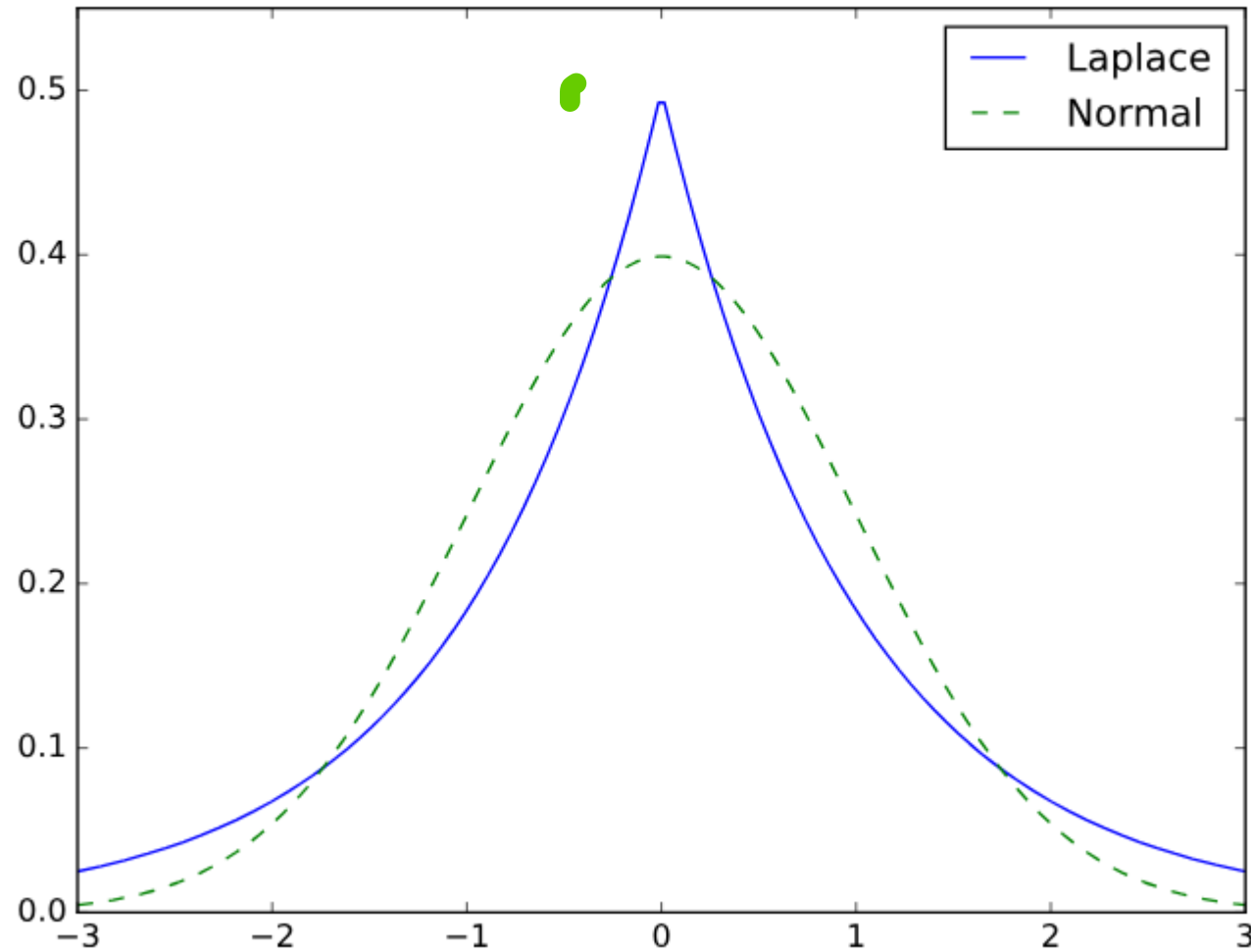


## Variability in neural responses





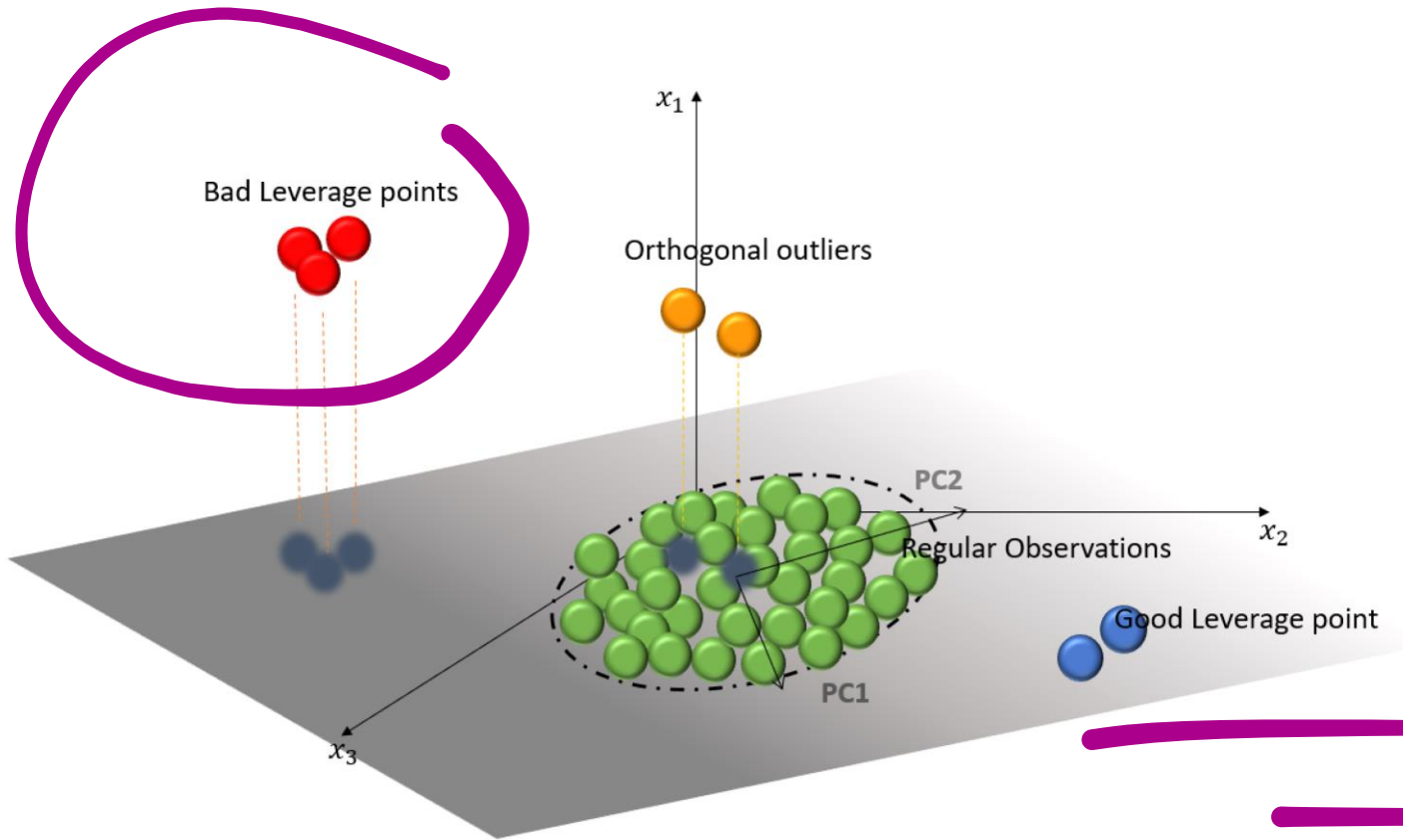
تمرین هفتگی:  
outlier ها در توزیع لاپلاسی در کجا هستند و چرا؟



# Why yes & Why Not!



# Good or Bad Outliers



16



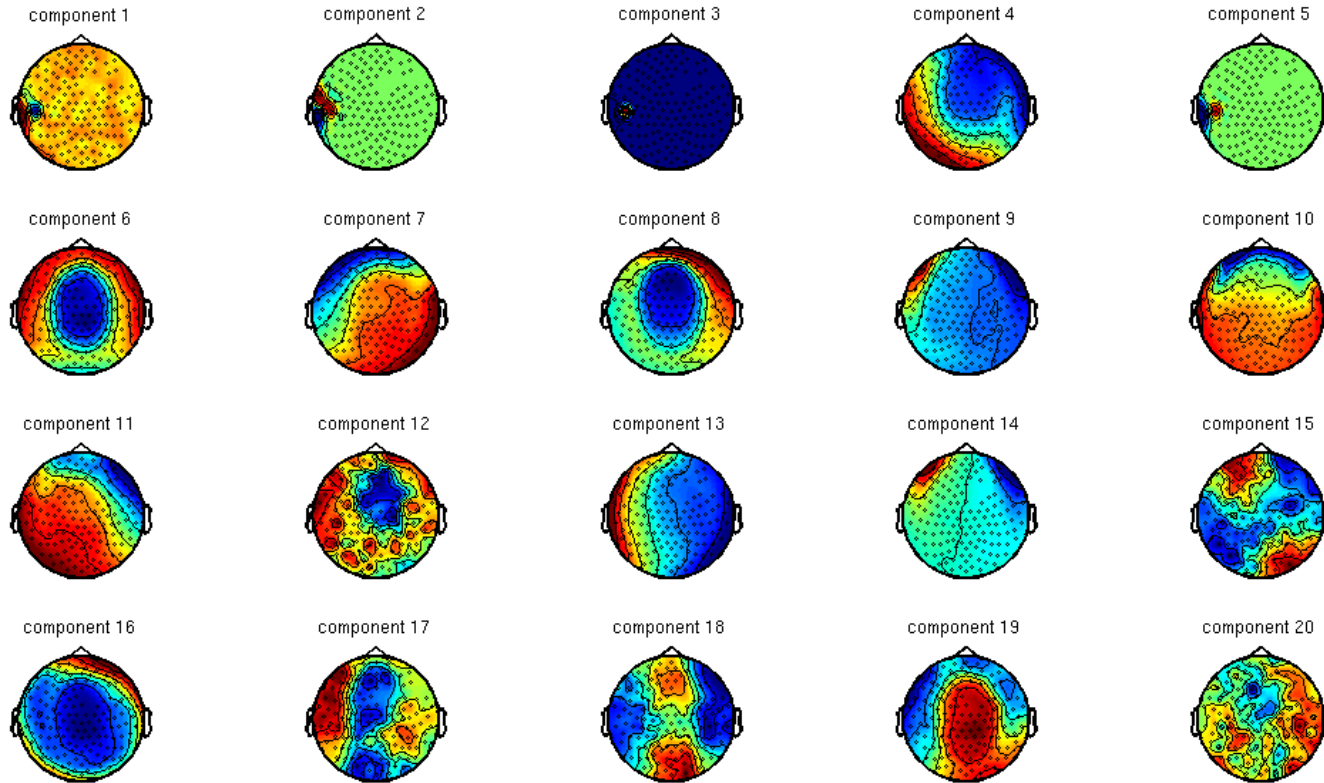
## Outliers

THE  
STORY  
OF SUCCESS

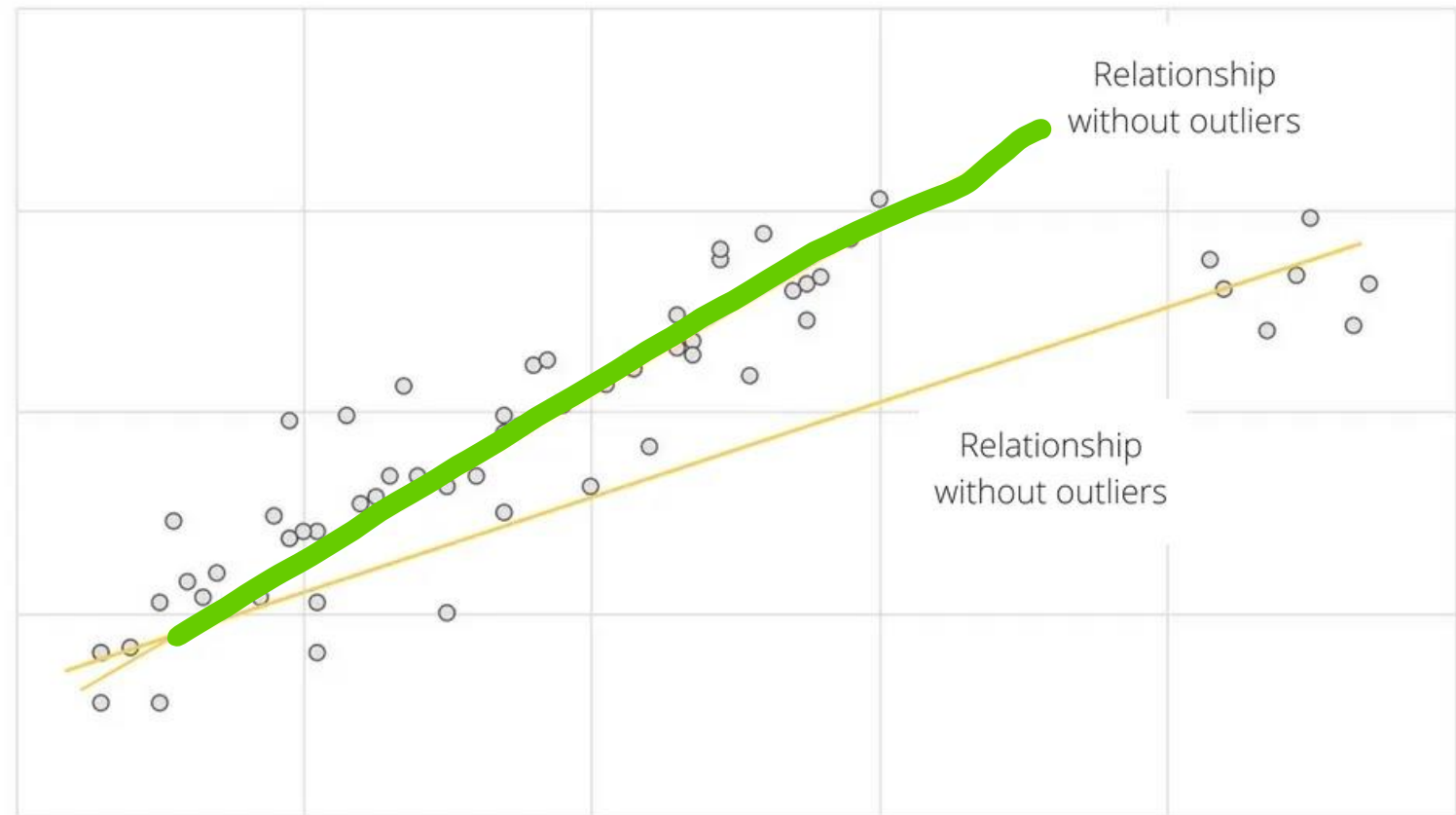
Malcolm  
Gladwell

# Outliers in ICA

17



# With or without outliers

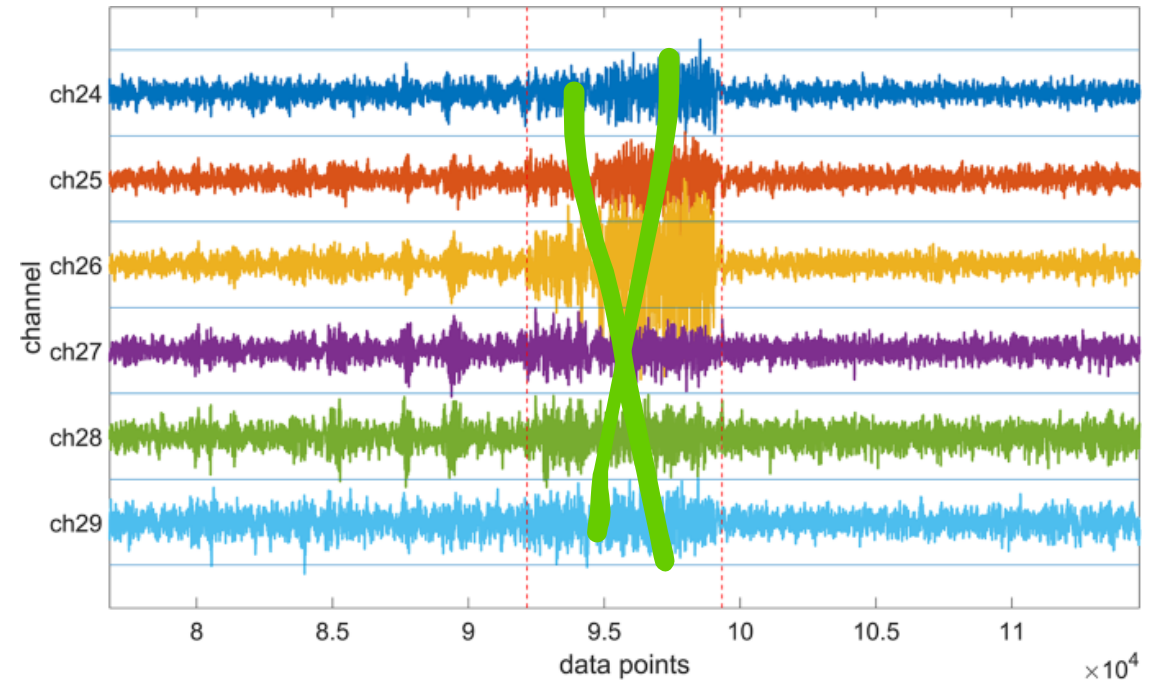
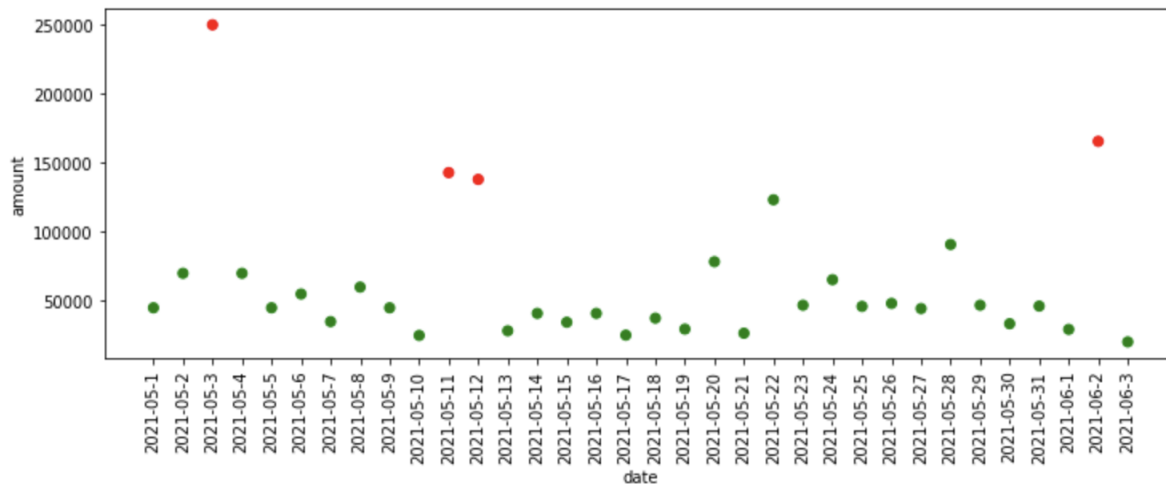




# Types of Outliers

## Univariate Outlier

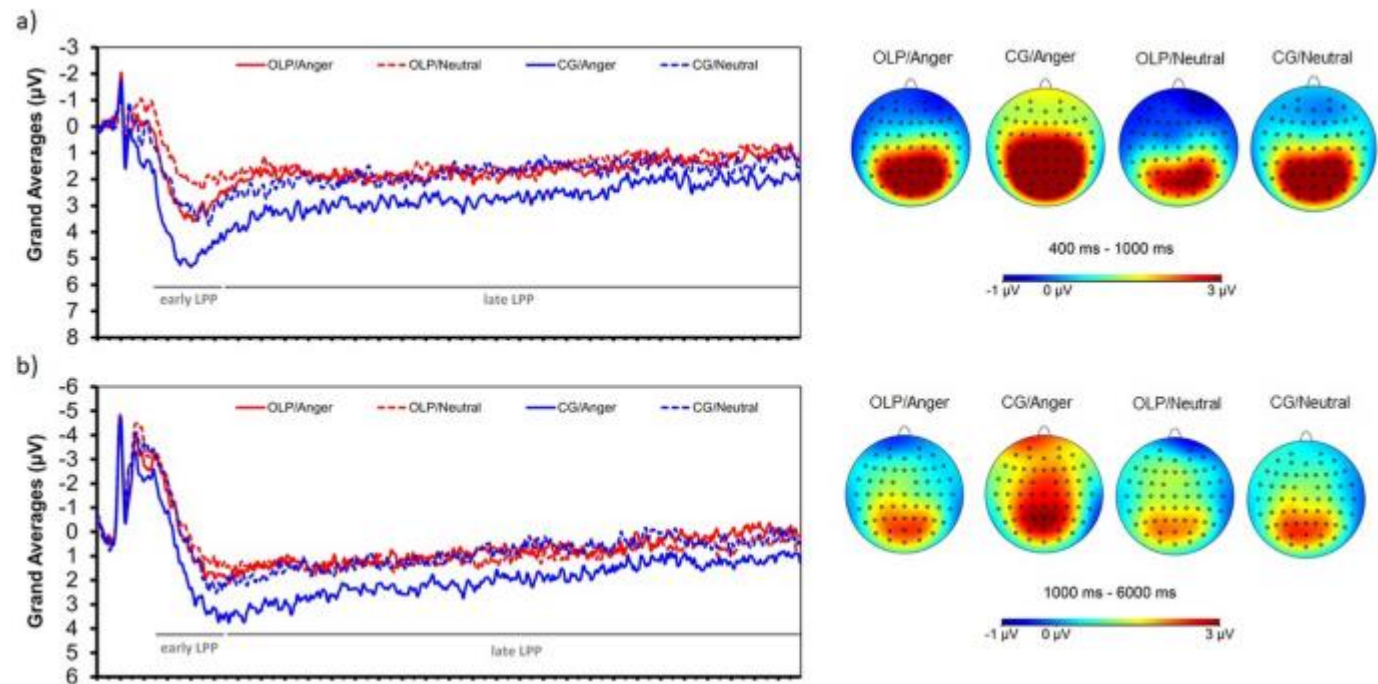
- A univariate outlier is a data point that is significantly different from the other points within a single variable (or feature) in a dataset. It is an extreme value in the distribution of that one variable, regardless of its relationship with any other variables.



# Types of Outliers

## Multivariate Outlier

A multivariate outlier is a data point that has an unusual combination of values across two or more variables. Individually, the values for each variable might not be outliers, but when examined together, they are anomalous.



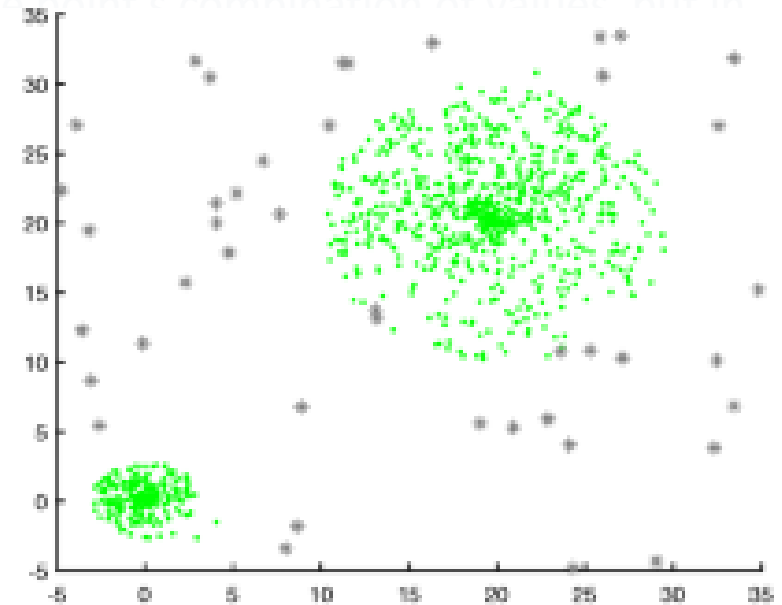
# Types of Outliers

## Collective Outlier

A collective outlier is a collection of data points that, as a whole, exhibit anomalous behavior compared to the entire dataset, even if the individual data points themselves are not outliers.

The key idea is that the anomaly is not in a single value or a single point's combination of values, but in the pattern, trend, or grouping of multiple points.

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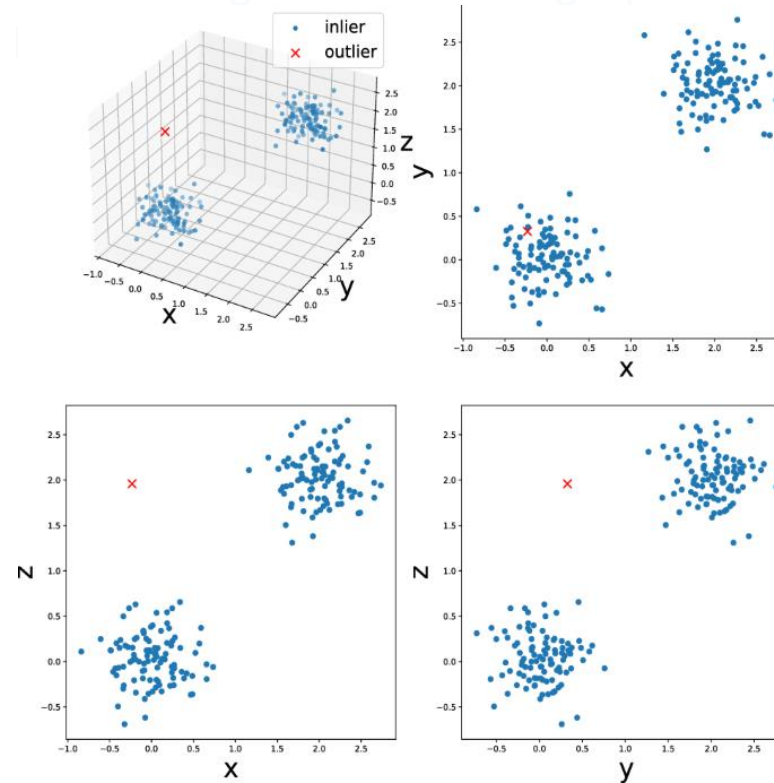
# Types of Outliers

## Contextual outlier

A contextual outlier is a data point that is considered anomalous only within a specific context or condition. Outside of that context, the same value might be perfectly normal.

The key idea is that you cannot determine if a point is anomalous without considering its contextual attributes (which define the situation) and its behavioral attributes (which are being evaluated within that situation).

The key idea is that the anomaly is not in a single value or a single point's combination of values, but in the pattern, trend, or grouping of multiple



# Types of Outliers

## Point/Global Outlier

A Point Outlier (also known as a Global Outlier) is a single data point that is significantly different from all other data points in the dataset, regardless of context or relationship with other variables.

"Point": It refers to a single, individual observation.

"Global": Its anomalous nature is obvious from a global perspective of the entire dataset; it doesn't require a specific context or a relationship with other variables to be identified. Idea is that the anomaly is not in a single value or a single point's combination of values, but in the pattern, trend, or grouping of multiple points.

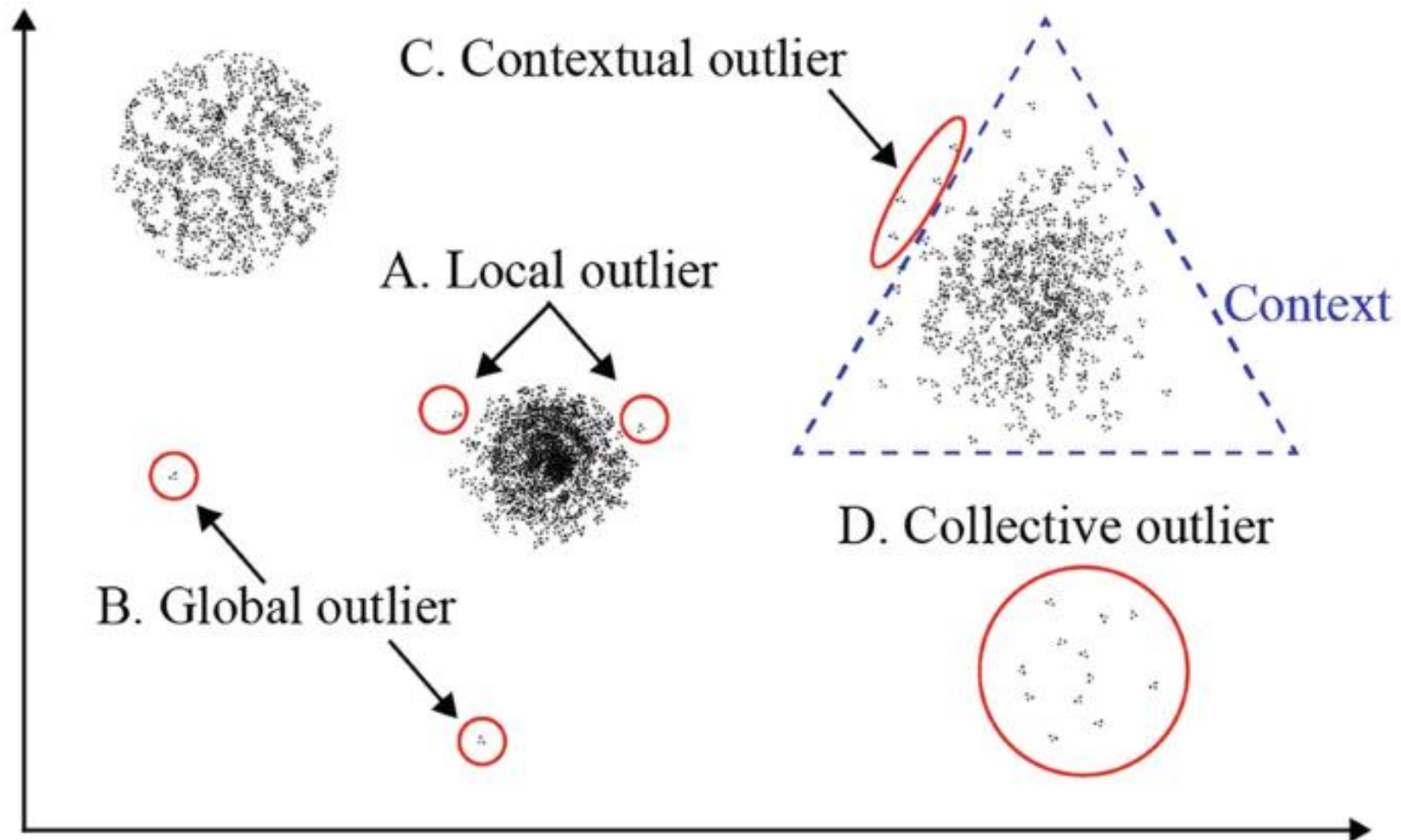




# Types of Outliers

Type of Outlier	Description	Detection Approach
<b>Point/Global Outlier</b>	An individual data point significantly distant from the rest of the dataset.	Univariate analysis (e.g., Z-score, IQR).
<b>Contextual Outlier</b>	A point anomalous under specific conditions (e.g., time/space) but normal otherwise.	Regression models, time-series analysis.
<b>Collective Outlier</b>	A group of points that collectively deviate from the dataset (individual points may not be outliers).	Cluster analysis, sequence mining.
<b>Multivariate Outlier</b>	An outlier detectable only through combinations of multiple variables.	Mahalanobis distance, PCA, clustering.
<b>Univariate Outlier</b>	An outlier detectable in a single feature/dimension.	Box plots, histograms, Z-scores.

## Types of Outliers



# DETECTION APPROACH

Method	Type	Data Type	Key Strength	Key Weakness
IQR / Box Plot	Statistical	Univariate	Simple, robust, non-parametric	Univariate only
Z-Score	Statistical	Univariate	Simple, fast	Assumes normality, sensitive to outliers
k-Nearest Neighbors (k-NN)	Proximity/Distance-Based	Multivariate	Simple intuition, no training phase	Computationally expensive, suffers from "curse of dimensionality"
Local Outlier Factor (LOF)	Proximity	Multivariate	Handles clusters of different densities	Computationally expensive, sensitive to parameters
Isolation Forest	Ensemble	Multivariate	Fast, works well in high-dimensions, handles multimodal data	Struggles with local outliers (high-density regions)
DBSCAN	Clustering	Multivariate	Finds clusters & outliers of arbitrary shape	Sensitive to distance and density parameters
K-Means	Clustering	Multivariate	Simple, fast, integrates with clustering	Assumes spherical clusters, sensitive to initial centroids and k
Principal Component Analysis (PCA)	Linear Model	Multivariate	Excellent for correlated, high-dim data; reduces noise	Limited to linear relationships, interpretation can be complex
One-Class SVM	Linear Model	Multivariate	Effective for non-linear boundaries (with kernel)	Slow on large datasets, sensitive to parameters
Autoencoder	Neural Network	Complex/High-Dim	Powerful for complex, non-linear data like images	Requires significant data and resources, "black box" model