

my-ebook

Parmeshvar

2025-07-06

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1 Introduction

2 Introduction

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3 Bayesian data analysis for cognitive science

3.1 Introduction: What this course is about

This course provides an introduction to Bayesian data analysis using the probabilistic programming language **Stan**.

We will use a front end software package called **brms**.

This course is for:

- Linguistics (MM5, MM6)
- Cognitive Systems
- Cognitive Science

Please see the [PULS FAQs](#) to find out how the sign-up system works (in German).

We will be using the software [R](#) and [RStudio](#), so make sure you install these on your computer.

Topics to be covered:

1. Basic probability theory, random variable theory (including jointly distributed RVs), probability distributions (including bivariate distributions)
2. Using Bayes' rule for statistical inference
3. An introduction to (generalized) linear models
4. An introduction to hierarchical models
5. Measurement error models
6. Mixture models
7. Model selection and hypothesis testing (Bayes factor and k-fold cross-validation)

3.2 Teaching

Science and statistics is/are one unitary thing; you cannot do one without the other. Towards this end, I teach some (in my opinion) critically important classes that provide a solid statistical foundation for doing research in cognitive science.

Courses offered:

1. Free online course, four weeks (MOOC), enrollments open: Introduction to Bayesian Data Analysis
2. Short (four-hour) tutorial on Bayesian statistics, taught at EMLAR 2022: [here](#)
3. Introduction to (frequentist) statistics
4. Introduction to Bayesian data analysis for cognitive science
5. BDA cover

3.3 Lecture notes

Download from [here](#).

3.4 Moodle website

All communications with students in Potsdam will be done through [this website](#).

4 Schedule

Week	Lecture	Main Topic	Sub Topic	Video	PDF Resource
Jan 30 + Feb 4	-	Model Selection & Hypothesis Testing	-	-	HW 13
Week 2	1	Descriptive Statistics	Central Tendency	Link	Week 2.pdf
	2	Descriptive Statistics	Measure of Variability	Link	Week 2.pdf
	3	Descriptive Statistics	Describing Data	Link	Week 2.pdf
	4	Probability	-	Link	Week 2.pdf
	5	Distribution	-	Link	Week 2.pdf
Week 3	1	Probability	Z Table (Normal Distribution)	Link	Week 3.pdf
	2	Divergence	Measuring Divergence	Link	Week 3.pdf
	3	Inferential Statistics	Sample and Population	Link	Week 3.pdf
	4	Model Fit	-	Link	Week 3.pdf
	5	Hypothesis Testing	Hypothesis and Error	Link	Week 3.pdf
Week 4	1	Statistical Terms	Terms of Statistics	Link	Week 4.pdf
	2	Hypothesis Testing	T-Test	Link	Week 4.pdf
	3	Hypothesis Testing	T-Test in Detail	Link	Week 4.pdf
	4	ANOVA	ANOVA	Link	Week 4.pdf
Week 5	1	ANOVA	Example of ANOVA	Link	Week 5.pdf
	2	ANOVA	Types of ANOVA	Link	Week 5.pdf
	3	Correlation	Introduction to Correlation	Link	Week 5.pdf
	4	Regression	Regression	Link	Week 5.pdf
Week 6	5	Regression	Regression	Link	Week 5.pdf
	1	Regression	R Script for Regression	Link	Week 6.pdf
	2	Chi-Square	Chi Square	Link	Week 6.pdf

Week	Lecture	Main Topic	Sub Topic	Video	PDF Resource
Week 7	3	Chi-Square	Chi Square Test	Link	Week 6.pdf
	4	Logistic Regression	Logistic Function	Link	Week 6.pdf
	5	Distribution	-	Link	Week 6.pdf
	1	Time Series	Intro to Time Series	Link	Week 7.pdf
	2	Probability	Conditional Probability	Link	Week 7.pdf
	3	Additional Concepts	-	Link	Week 7.pdf
	4	Distribution	-	Link	Week 7.pdf
	5	Poisson Distribution	-	Link	Week 7.pdf
	1	Libraries & Documentation	Effect Size and Packages	Link	Week 8.pdf
	2	Software Comparison	RStudio vs RKward	Link	Week 8.pdf
Week 8	3	Visualization	Flexplot	Link	Week 8.pdf
	4	Programming in R	Functions	Link	Week 8.pdf
	5	R Tools	R Shiny and R Markdown	Link	Week 8.pdf

5 Introduction to Statistics

6 Chapter 1: Welcome and Course Overview

This course offers an introduction to statistics through the RKWard graphical interface of R. Aimed at learners from diverse backgrounds, the course emphasizes practical application over theory. You don't need a strong background in math or computing—just an eagerness to learn.

Pre-Requisites:

- Curiosity
- Basic awareness of numbers
- No fear of statistics or software

“Aapko darne ki zarurat nahi hai... simple understanding aapko statistics ki data ki aage milegi.”

7 Chapter 2: Agenda and Orientation

Key Themes:

- Difference between Mathematics and Statistics
- Nature, Meaning, and Role of Statistics
- Uses, Limitations, and Common Fallacies

Aspect	Mathematics	Statistics
Nature	Abstract, theoretical	Applied, data-centric
Focus	Concepts, theorems, proofs	Tools, interpretation, decision-making
Tools	Logical reasoning, algebra	Hypothesis testing, regression, probability
Application	General structures	Real-world problems

8 Chapter 3: Meaning and Nature of Statistics

Definition:

Statistics is the science of collecting, analyzing, interpreting, and presenting data for decision-making.

Core Concepts:

- Population & Sample
- Parameter & Statistic
- Data classification and tabulation

Purpose:

- Describe and explain phenomena
- Interpret and predict outcomes
- Facilitate scientific and social inquiry

9 Chapter 4: Applications and Uses

Main Uses:

- Summarizing observed data
- Drawing representative samples
- Analyzing relationships and trends
- Supporting decision-making in fields like marketing, psychology, education, and public health

Important Concepts:

- Data summarization
- Prediction based on patterns
- Comparison across groups
- Scientific objectivity

10 Chapter 5: Limitations and Misuse

Limitations:

- Cannot analyze qualitative phenomena
- Not designed for individuals
- Results aren't exact
- Misinterpretation leads to incorrect conclusions

Misuse Includes:

- Small or biased samples
- Misleading graphs
- Invalid comparisons

“Statistics is not a substitute for common sense or understanding the context.”

Fallacies Stem From:

- Poor data collection
- Mislabeling variables
- Improper classification or selection

11 Chapter 6: Paper-Based vs. Software-Based Statistics

Traditional exams test pen-paper knowledge, but software-based tools like RKWard make analysis:

- Faster
- Collaborative
- Easier to store and access
- Essential for modern data-centric fields like AI and machine learning

Understanding both paper and digital approaches ensures comprehensive learning.

12 Chapter 7: Introduction to Variables and Spreadsheets

Variables:

- Store information (e.g., $x = 5$)
- Have unique names
- Can be manipulated with commands (e.g., $x = x + 2$)

Spreadsheets:

- Represent tabular data (rows = observations, columns = variables)
- Familiar formats: Excel, Google Sheets
- Essential in statistical packages

13 Chapter 8: R and GUI Interfaces

Why R?:

- Free and open-source
- Strong community support
- High flexibility
- Powerful graphics and data manipulation capabilities

GUI Tools in R:

- RKWard (*used in this course*)
- R Commander
- Rattle
- R AnalyticFlow

Basic Terms:

- **Console:** Type commands & view outputs
- **Working Directory:** File storage location
- **Package:** Predefined or custom functions
- **Script:** Collection of reusable commands
- **Workspace:** All current variables/functions

14 Chapter 9: Importing Data and Understanding Data Types

Using RKWard:

- Import CSV files using GUI
- Data appears in alphabetical order in workspace
- Each header = variable name

Data Structures:

- Data Frames (most commonly used)
- Matrices
- Vectors
- Lists

Command Line vs GUI:

- Both achieve the same results
- GUI is user-friendly, command line is customizable

```
mean(my_csv.data$JP_01) # Calculates the mean of variable JP_01
```

15 Chapter 10: Statistical Data Types

Statistical Type	Description	R Equivalent
Nominal	Names, labels (e.g., Male/Female)	String
Ordinal	Order/rank (e.g., 1st, 2nd)	Factor
Interval	Ordered + meaningful intervals (e.g., tax slabs)	Numeric
Ratio	Includes absolute zero (e.g., weight)	Numeric

Others in R:

- Logical (TRUE/FALSE)
- Integer, Complex

Remember: Not all numbers mean quantity. Shirt numbers (like #18) are nominal, not mathematical.

16 Chapter 11: Data Preparation in RKWard

- Data must be properly **typed** (e.g., “1” as number vs “1” as label)
- Check alignment: Left = character, Right = number
- **Labels** help collaborators understand variables
- Example: `Gender = 1` (Male), `0` (Female)
- Must distinguish between numeric calculations and categorical identifiers

Best Practices:

- Define each variable with meaning
- Validate data types
- Store and share workspace for reproducibility

17 Chapter 12: Visualizing Data with Plots in RKWard

Data visualization is essential to reveal patterns, trends, and distributions. RKWard offers multiple graphical tools:

17.1 1. Histogram

- Depicts the distribution of a single variable
- Can include frequency, relative frequency, and cumulative frequency
- Best for understanding where most data points lie

17.2 2. Pie Chart

- Represents categorical data as slices of a circle
- Best when visualizing proportions

17.3 3. Scatter Plot

- Plots two variables to examine relationships
- X-axis: Independent variable
- Y-axis: Dependent variable
- Useful in exploring associations or potential causality

17.4 4. Box Plot

- Shows data distribution via quartiles
- Median, interquartile range (IQR), and outliers are clearly indicated

- Useful for comparing multiple variables

17.5 5. Density Plot

- Smoothed version of a histogram
- Better suited for continuous data with decimal variation

Key Tips:

- JP_01 was frequently used as an example variable
- RKWard allows saving and exporting plots easily
- GUI menus guide the user through plot creation

Always choose the plot type that best matches your data and goal: frequency, relationship, or comparison.

18 Chapter 13: Summary

This eBook provided a foundation for understanding and applying statistics using the RKWard GUI tool in R. It covered essential concepts from what statistics is, to importing and handling data, understanding types of variables and their measurement levels, and visualizing data using a variety of plots.

Learners were introduced to:

- Basic statistical principles
- Software versus paper-based understanding
- Variable types and spreadsheet usage
- Command line and GUI-based tools
- Data visualization through histogram, pie, scatter, box, and density plots

The course emphasized **conceptual clarity**, **practical tools**, and the **power of visualization**. It prepares learners to interpret, analyze, and present data meaningfully in academic or real-world contexts.

19 References

1. Mohanty, B., & Misra, S. (2020). *Statistics for Behavioral and Social Sciences*. PHI Learning.
2. Pandya, D., et al. (2019). *Statistical Analysis in Simple Steps Using R*. Wiley.
3. Field, A., Miles, J., & Field, Z. (2012). *Discovering Statistics Using R*. SAGE Publications.
4. Harris, J. (2021). *Statistics with R: Solving Problems Using Real-World Data*. Pearson.
5. RKWard Project: <https://rkward.kde.org>

20 Next Steps

Upcoming lectures will cover:

- Graph creation
- Data visualization tools
- Advanced statistical operations in GUI

21 basic-statistics_1

22 Introduction

Welcome to the “Basic Statistics Using GUI-R (RK Ward)” course, led by Dr. Harsh Pradhan at the Institute of Management Studies, Banaras Hindu University. This course takes an integrated approach to statistical analysis, bridging theory with practical skills through the R programming language and its GUI, RKWard.

22.1 Objectives of the Course

- Understand fundamental concepts related to statistics.
- Gain proficiency in using R and RKWard for statistical analysis.
- Learn to visualize data effectively.
- Apply statistical methodologies to real-world datasets.

23 Overview of R and RKWard

23.1 R Programming Language

R is a versatile, open-source language specifically designed for statistical analysis and data visualization. It provides an extensive suite of statistical procedures, making it a cornerstone for statisticians and data scientists.

Key Features of R:

- **Extensive Libraries:** R hosts thousands of packages that support numerous statistical models such as linear regression, time series, and more.
- **Customizable Graphics:** The base graphics capabilities, along with packages like `ggplot2`, allow users to create a variety of complex visualizations with relative ease.
- **Data Manipulation Tools:** Packages like `dplyr` and `tidyr` provide robust tools for data cleaning and transformation.

23.2 Understanding RKWard

RKWard serves as a user-friendly interface that simplifies interactions with R, allowing users—especially those less familiar with programming—to utilize its powerful capabilities without a steep learning curve.

Features of RKWard Include:

- **Graphical User Interface:** Navigation through menus rather than command lines enhances accessibility.
- **Built-in Documentation:** Context-sensitive help facilitates learning and troubleshooting.
- **Integration with R:** Commands executed via the GUI can be viewed and modified, providing a dual-learning experience.

24 Understanding Variables

24.1 Types of Variables

Variables are the building blocks of statistical analysis, representing the characteristics or properties of the data.

24.1.1 Qualitative Variables (Categorical Variables)

- **Nominal Variables:** These variables categorize data without an inherent order. For example, types of fruits (apple, orange) are nominal.
- **Ordinal Variables:** These represent ordered categories. For instance, a customer satisfaction survey may be rated as poor, fair, good, or excellent.

24.1.2 Quantitative Variables

- **Discrete Variables:** These variables take on countable values, such as the number of students in a class.
- **Continuous Variables:** These can take any value within a given range, such as height and weight.

24.2 Importance of Defining Variables

Properly understanding and defining variables is crucial for:

- Selecting appropriate statistical tests.
- Ensuring accurate data interpretation.
- Structuring datasets to facilitate analysis.

25 Data Types and Spreadsheet Concepts

25.1 Statistical Data Types

Data types are foundational for statistical analysis as they define what kind of arithmetic operations can be performed on the data.

Data Type	Description	Example
Nominal	Categorical data without order	Blood types (A, B, AB, O)
Ordinal	Categorical data with a defined order	Customer satisfaction (poor, fair, good)
Interval	Numerical data with meaningful differences	Temperature in Celsius
Ratio	Numerical data with an absolute zero	Weight, height

25.2 Spreadsheet Basics

Spreadsheets provide a structured format for data entry, where rows represent instances (e.g., individuals, items) and columns represent variables (e.g., age, gender).

Key Functions of Spreadsheets:

- Data Organization: Data is easily sorted and filtered.
- Formulas and Functions: Built-in functions allow for quick calculation and data manipulation.
- Visualization Integration: Charts and tables can visually represent data.

26 Importing Data in RKWard

26.1 Data Preparation

Before importing data into RKWard, ensure that your dataset meets standards such as:

- Properly labeled columns.
- Consistent data types.
- Absence of unnecessary formatting or symbols.

26.2 Step-by-Step Import Process

Steps to import data into RKWard:

1. Open RKWard and access the main interface.
2. Go to the “Data” tab and select “Import Data”.
3. Choose the file type such as CSV or Excel.
4. Browse to locate your file.
5. Specify data types for each column during import and ensure the first row contains headers.
6. Review the imported data in the workspace to confirm it’s properly loaded.

27 Basic Statistical Practices

27.1 Descriptive Statistics

Descriptive statistics help summarize and organize data in a meaningful way.

27.1.1 Central Tendency Measures

- **Mean:** Average of the dataset.
- **Median:** Middle value when data is ordered.
- **Mode:** Most frequent value in the dataset.

Measure	Formula	Description
Mean	$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$	Average value
Median	(Sorted data, middle item)	Middle value in ordered dataset
Mode	Value that appears most frequently	Most common value

27.1.2 Dispersion Measures

- **Range:** Difference between the maximum and minimum values.
- **Variance:** Measurement of the spread of data points.
- **Standard Deviation:** Square root of variance, providing a measure of the average distance from the mean.

Measure	Formula	Description
Range	$Range = Max - Min$	Spread of dataset
Variance	$Var(X) = \frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}$	Spread of data relative to mean
Standard Deviation	$SD(X) = \sqrt{Var(X)}$	Average distance from mean

27.2 Inferential Statistics

Inferential statistics allow us to make predictions or inferences about a population based on a sample.

- **Hypothesis Testing:** A method to test assumptions regarding population parameters using sample data.
- **Confidence Intervals:** Define a range of values derived from sample statistics that likely encompass the true population parameter.

27.3 Practical R Commands and Functions

Understanding and utilizing R functions is crucial for effective data analysis. Some key functions include:

- `mean()`: Calculates the average.
- `sd()`: Computes standard deviation.
- `t.test()`: Performs a t-test for hypothesis testing.

28 Visualizing Data with Graphs

28.1 Significance of Data Visualization

Visualization enhances comprehension by allowing researchers to observe patterns, trends, and anomalies effectively.

28.2 Types of Graphs

Variety in graph types caters to different data presentation needs:

Graph Type	Use Case
Bar Graph	Comparing categorical data
Histogram	Displaying distribution of continuous data
Box Plot	Summarizing data distributions and spotting outliers
Scatter Plot	Investigating relationships between two quantitative variables

28.3 Implementing Visualization in RKWard

Students will learn how to create visualizations within RKWard by following these steps:

1. Navigate to the graph creation menu.
2. Select the desired type of graph.
3. Customize visual elements such as titles, colors, and axes.
4. Generate and export the graph for use in reports.

29 Practical Applications of Statistics

29.1 Case Studies in Various Fields

Statistics plays a pivotal role in diverse disciplines:

Field	Application
Healthcare	Analyzing medical test results, outcomes of treatments, and patient demographics
Business	Applied for market analyses, customer satisfaction studies, and financial forecasting
Social Sciences	Employed in surveys to understand populations, opinions, and behavioral patterns

29.2 Utilizing Statistical Methods for Decision Making

- Use statistical evidence to guide business strategies.
- Make informed policy decisions based on empirical data.
- Report findings clearly for transparency and comprehension.

30 Summary

The “Basic Statistics Using GUI-R (RK Ward)” course equips learners with the foundational and practical skills needed for statistical analysis using R. Students will understand theoretical concepts, grasp practical applications, and use RKWard effectively to analyze real-world data.

30.1 Key Takeaways

- Proficiency in defining and using variables and data types.
- Capability to import and manipulate data in RKWard.
- Understanding of basic statistical practices and their applications.
- Skill in visualizing data for effective communication of results.

31 basic-statistics_2

32 Introduction

32.1 Purpose of the eBook

This eBook aims to provide a comprehensive understanding of basic statistics, focusing on the essential principles necessary for data analysis.

32.2 Importance of Statistics

Statistics is critical in interpreting data efficiently and effectively across disciplines.

33 Basic Concepts of Statistics

33.1 Overview of Statistics

Statistics is the discipline that deals with the collection, analysis, interpretation, and presentation of data.

33.2 Types of Data

- **Qualitative Data:** Represents categories or labels without numeric value (e.g., gender, religion).
- **Quantitative Data:**
 - **Discrete Data:** Countable values (e.g., number of students).
 - **Continuous Data:** Measurable values (e.g., height, weight).

33.3 Descriptive vs. Inferential Statistics

- **Descriptive Statistics:** Summarizes or describes the characteristics of a dataset.
- **Inferential Statistics:** Makes predictions or inferences about a population based on a sample.

34 Measures of Central Tendency

34.1 Definition and Importance

Measures of central tendency describe the center point or typical value of a dataset.

34.2 The Mean

The mean is the arithmetic average of a dataset.

34.2.1 Example

Consider the data: 2, 3, 5, 7, 11
Mean = $\frac{2+3+5+7+11}{5} = \frac{28}{5} = 5.6$

34.3 The Median

The median is the middle value in an ordered dataset.

34.3.1 Example

Consider the data: 3, 5, 1, 7, 9
Ordered: 1, 3, 5, 7, 9 \rightarrow Median = 5

34.4 The Mode

The mode is the value that appears most frequently in a dataset.

34.4.1 Example

Data: 2, 4, 4, 5, 5, 5, 7, 8
Mode = 5

34.5 Comparison of Measures

Measure	Description	Strengths	Limitations
Mean	Average of all data points	Utilizes all data	Sensitive to outliers
Median	Middle value	Robust to outliers	Ignores extreme values
Mode	Most frequent value	Useful for categorical data	May not exist or be unique

35 Measures of Variability

35.1 Definition and Importance

Measures of variability indicate the spread or dispersion within a dataset.

35.2 Range

The range is the difference between the maximum and minimum values.

35.2.1 Example

Data: 4, 8, 2, 10, 6
Range = $10 - 2 = 8$

35.3 Variance

Variance is the average of the squared deviations from the mean.

35.3.1 Example

Data: 2, 4, 4, 4, 5, 5, 7
Mean = 4.43 (approx.)
Variance = $\frac{\sum (x_i - \bar{x})^2}{n-1}$

35.4 Standard Deviation

Standard deviation is the square root of the variance.

35.5 Interquartile Range (IQR)

The IQR measures the middle 50% of the data between Q1 and Q3.

35.5.1 Example

Data: 1, 2, 3, 4, 5, 6, 7, 8, 9

$Q1 = 3, Q3 = 7$

$IQR = 7 - 3 = 4$

36 Probability Fundamentals

36.1 Introduction to Probability

Probability measures the likelihood of occurrence of an event.

36.2 Types of Events

- **Independent Events:** One event does not affect another.
- **Dependent Events:** One event influences the outcome of another.
- **Mutually Exclusive Events:** Events that cannot happen at the same time.

36.3 Basic Probability Rules

1. **Addition Rule:** This rule applies when you're calculating the probability of event A **or** event B occurring.

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

2. **Multiplication Rule:** This rule applies when you're calculating the probability of event A **and** event B both occurring (for independent events).

$$P(A \cap B) = P(A) \times P(B)$$

36.4 Introduction to Probability Distributions

36.4.1 Normal Distribution

- Symmetric about the mean.
- Bell-shaped curve.
- Properties: Mean = Median = Mode.

37 Detailed Transcripts

37.1 Transcript from Lec06

Key Discussion Points: - Effects of outliers on the mean. - Properties of the mean.

37.2 Transcript from Lec07

Key Discussion Points: - Concepts of range, variance, and standard deviation.

37.3 Transcript from Lec08

Key Discussion Points: - Explanation of the Z score. - Galton board demonstration.

37.4 Transcript from Lec09

Key Discussion Points: - Introduction to probability distributions. - Basic probability concepts and terms.

38 Summary of Week 2 Content

- Measures of central tendency.
- Measures of variability.
- Basic probability and events.
- Introduction to distributions.

39 Tables and Visualizations

39.1 Frequency Distribution Example

Value	Frequency
1	4
2	6
3	3
4	2
5	1

39.2 Interquartile Range Example

Position	Value
1	12
2	30
3	45
4	57
5	70

$$\text{IQR} = 57 - 30 = 27$$

39.3 Box Plot Visualization

A box plot visualizes:

- Minimum
- First Quartile ($Q1$)
- Median
- Third Quartile ($Q3$)
- Maximum

40 References

41 Appendices

- Additional exercises
- Data sets for practice
- Online resources and guides on RKWard