**Statistical Methods**

1. Independent T-test (Parametric)
   (a) Normality, Homogeneity of Variances, Independence
   (b) Comparing means of two independent groups

   **Process**

   1. Calculate the means $\mu = \frac{\sum_{i=0}^{n} x_i}{n}$,

   2. Calculate the standard deviation $\sigma^2 = \sqrt{\frac{\sum_{i=0}^{n} x_i - \mu}{n-1}}$,

   3. Calculate the pooled standard deviation $\sqrt{\frac{(n_A-1)s_A^2+(n_B-1)s_B^2}{n_A+n_B-2}}$,

   4. Calculate the t-Statistic $\frac{\bar{X_A}-\bar{X_B}}{s_p\sqrt{\frac{1}{n_A}+\frac{1}{n_B}}}$,

   5. Determine the critical value and Compare $df = n_A + n_B - 2$.

   6. reject $H_O : |t| >$ critical value; accept $H_O : |t| \leq$ critical value

2. Mann-Whitney U test (Non-Parametric)
   (a) Independence, Continuous/Ordinal data
   (b) Comparing distributions of two independent groups

   **Process**

   1. Combine and rank data,

   2. Assign individual ranks,

   3. Calculate the sum of the ranks, 4. Compute for the U statistic for the samples and choose the minimum, $U_A = n_A \cdot n_B + \frac{n_A(n_A+1)}{2}; U_B = n_A \cdot n_B + \frac{n_B(n_B+1)}{2}; U = \min(U_A, U_B)$,

   5. Determine the critical value and Compare $n_A, n_B$ at $\alpha = 0.05$.

   6. reject $U <$ critical value; accept $H_O : U \geq$ critical value

3. Paired t-test (Parametric)
   (a) Normality of differences, Independence of Pairs
   (b) Comparing means of paired observation (cause/effect)

   **Process**

   1. Calculate the differences,

   2. Calculate the mean difference,

   3. Calculate the standard deviation of the difference,

   4. Calculate the t-Statistic,

   5. Determine the critical value and Compare $df = n - 1 at \alpha = 0.05$.

   6. reject $H_O : |t| >$ critical value; accept $H_O : |t| \leq$ critical value

4. Wilcoxon Signed-Rank Test (Non-Parametric)
   (a) Paired data, Continuous/Ordinal data
   (b) Comparing distributions of paired observations (cause/effect)

   **Process**

   1. Calculate the differences and absolute values,

   2. Rank absolute differences,

   3. Assign ranks with signs,

   4. Calculate test statistic,

   5. Determine the critical value and Compare $n\alpha = 0.05$.

   6. reject $H_O : W \leq$ critical; accept $H_O : W >$ critical

5. RMANOVA (Parametric)
   (a) Normality, Sphericity, Independence of Variances
   (b) Comparing means of related groups measured under different conditions

   **Process**

   1. Calculate the group mean,

   2. Calculate the overall mean,

   3. Calculate the Total Sum of Square $SST = \sum(X_{ij} - \bar{X})^2$,

   4. Calculate the Between-Groups Sum of Squares $SSB = \sum n_i(\bar{X}_i - \bar{X})^2$

   5. Determine the SSW $SSW = SST - SSB$.

   6. Calculate the Between-Groups Degrees of Freedom $df_B = k - 1$

   7. Calculate the Within-Groups Degrees of Freedom $df_w = N - k$

   8. Calculate the Mean Square Between $MSB = \frac{SSB}{df_B}$

   9. Calculate the Mean Square Within $MSW = \frac{SSW}{df_W}$

   10. Calculate the F statistic $F = \frac{MSB}{MSW}$

   11. Determine the critical value and Compare

   12. accept $H_O : F_{\text{comp}} <$ critical value; reject $H_O : F_{\text{comp}} \geq$ critical value

6. Friedman Test (Non-Parametric)
   (a) Paired/Repeated measures, Continuous/Ordinal data
   (b) Comparing distributions of more than two related groups

   **Process**

   1. Rank each set of conditions for each transmitter,

   2. Calculate the sum of the ranks for each conditions,

   3. Calculate the Friedman test statistic using the chi-squared aprroximation $\chi_F^2 = \frac{12}{nk(k+1)} \sum R_j^2 - 3n(k+1)$,

   4. Determine critical value,

   5. reject $\chi <$ critical value; accept $\chi \geq$ critical value

7. One Way ANOVA (Parametric)
   (a) Normality, Homeogeneity of variances, Independence
   (b) Comparing the means of more than two groups

   **Process**

   Same as RMANOVA

8. Kruskal-Wallis Test (Non-Parametric)
   (a) Paired/Repeated measures, Continuous/Ordinal data
   (b) Comparing the distributions of more than two groups

**Process**

1. Combine and rank all data from all groups,

2. Sum the ranks for each group,

3. Calculate H statistic $H = \frac{12}{N(N+1)\sum_{R_i^2}^{n_i} - 3(N+1)}$,

4. Determine critical value,

5. accept $H_O : H >$ critical value; reject $H_O : H \leq$ critical value

9. Pearson R

   (a) Interval/Ratio data, Linearity, Homogeneity of Variances

   (b) Measures the strength and direction of relationship between variables

   **Process**

   1. Compute the mean of distances and the mean of signal strengths $\bar{x} = \frac{\sum_{i=0}^{n} X_i}{n}; \bar{y} = \frac{\sum_{i=0}^{n} Y_i}{n}$,

   2. Compute the mean of distances and the mean of signal strengths $\sum(x_i - \bar{x})(y_i - \bar{y})$,

   3. Calculate the sum of squared deviations $\sum(x_i - \bar{x})^2; \sum(y_i - \bar{y})$

   4. Compute for the Pearson R $r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})(y_i - \bar{y})}}$,

   5. **r value** $|-|$ **Interpretation**

   $r/\rho = 1 \mid - \mid$ Perfect positive linear/monotonic correlation; $1 > r/\rho \geq 0.8 \mid - \mid$ Strong positive linear/monotonic correlation; $0.8 > r/\rho \geq 0.4 \mid - \mid$ Moderate positive linear/monotonic correlation; $0.4 > r/\rho > 0 \mid - \mid$ Weak positive linear/monotonic correlation; $r/\rho = 0 \mid - \mid$ No correlation

10. Spearman Rho

    (a) Continuous/Ordinal data, Monotonic Relationship

    (b) Measures the strength and direction of relationship between variables

    **Process**

    1. Rank distances and strengths separately,

    2. Calculate the difference in ranks and square them,

    3. Compute the Spearman Rho $\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$

    4. Same conclusion as Pearson R

11. Linear Regression Parametric

    (a) Linearity, Independence, Homegeneity of Variances, Normality

    (b) For modeling and predicting the relationship between a dependent variable (Y) and one or more independent variables (X).

    **Process**

    1. Rank distances and strengths separately,

    2. Calculate the difference in ranks and square them,

    3. Compute the Spearman Rho $\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$

    4. Conclude

12. Multiple Regression Parametric

    (a) Linearity, Independence, Homeogeneity of Variances, No Multicollinearity

    (b) For modeling and predicting the relationship between a dependent variable (Y) and one or more independent variables (X).

    **Process**

    1. Calculate means $\bar{X} = \frac{\sum_{i=0}^{n} X_i}{n}; \bar{Y} = \frac{\sum_{i=0}^{n} Y_i}{n}$,

    2. Calculate slope,

    3. Calculate the y - intercept $a = \bar{Y} - b\bar{X}$,

    4. Write the regression equation

    5. Conclude

13. ANCOVA (Parametric)

    (a) Linearity, Homegeneity of Regression Slopes, Independence, Measurement of the Covariate

    (b) Compares a response variable by both a factor and a continuous independent variable

    **Process**

    1. Understand the given data

    2. Compute the Overall Mean for Transmission Rate,

    3. Compute the factor means,

    4. Compute for the adjusted means, if $\bar{X_A} = \bar{X_B} = \bar{X_C}$ then no adjustment

    5. Calculate the $SS_T$; $SS_B$ and $SS_W$

    6. accept $H_O : F_{\text{comp}} <$ critical value; reject $H_O : F_{\text{comp}} \geq$ critical value

14. MANOVA (Parametric)

    (a) Independence of Observations, Linearity, Adequate Sample Size

    (b) ANOVA with two or more continuous response variables

    **Process**

    (a) Understand the given data

    (b) Calculate the means

    (c) Calculate the slope $b_A = \frac{\sum(x_A - \bar{X_A})(Y_A - \bar{Y_A})}{\sum(X_A - \bar{X_A})^2}$

    (d) Calculate the slope $Y = Y_A + b_A(\bar{X} - \bar{X_A})$ and interpret the adjusted mean

15. MANCOVA (Parametric)

    (a) Independence of Observations, Linearity, Adequate Sample Size, Linearity and Homogeneity of Regression Slopes, Measurement of the Covariate

    (b) One or more covariates are added to the mix

16. $2^k$ Factorial design

    (a) Find the sum of squares: $A = \frac{ab+a-b-(1)}{4n}$; $B = \frac{ab+b-a-(1)}{4n}$; $AB = \frac{ab+b-a-(1)}{4n}$; $T = \sum_{i=1}^{2} x_{ijk}^2 - \frac{y^2}{4n}$; $E = T - (A + B + AB)$

    (b) Find the degree of Freedom: $a, b, ab = 1$; $E = 4(n-1)$; $T = 4n$

    (c) Find the Mean Square: $A = \frac{SS_A}{df}$; $B = \frac{SS_B}{df}$; $AB = \frac{SS_{AB}}{df}$

    (d) Find $F_0$: $A = \frac{MS_A}{MS_E}$; $B = \frac{MS_B}{MS_E}$; $\frac{MS_{AB}}{MS_E} and F_{(A,E)}(0.05)$

**Descriptive Statistic**

- summarizes or describes the characteristics of a data set

Absolute Frequency, Line Graph, Bar Graph, Frequency Polygon, Relative Frequency, Pie Chart

Class Frequency, Histogram, Cumulative Frequency Plot, Stem and Leaf

**Test of Hypothesis and Regression Models**

**Hypothesis** - testable statement about the relationship between two or more variables

**Hypothesis Testing** - Process to determine if there is enough evidence to reject a null hypothesis

**Null Hypothesis** - No effect or difference

**Alternative Hypothesis** - There is an effect or difference.

**What Makes a Good Hypothesis**

1. Testable, 2. Specific, 3. Based on Existing Knowledge, 4. Predictive.

**Importance of Assumptions in Hypothesis Testing**

1. Validity of Results, 2. Appropriate Test Selection, 3. Statistical Power and Efficiency.

**Common Assumptions for Parametric Tests**

1. Normality, 2. Homegeneity of Variances, Independence, No Outliers.

When any of the Assumptions is violated, it is said to be Non-Parametric

**Advantages of Non-Parametric Tests**

1. Flexibility, 2. Robustness.

**Disadvantages of Non-Parametric Tests**

1. Less Power

**Type I Error (False Positive)**

- occurs when the null hypothesis is TRUE but is incorrectly rejected

- it is denoted by alpha $\alpha$. To control, set at an acceptable significance level at $\alpha = 0.05$

**Type II Error (False Negative)**

- occurs when the null hypothesis is FALSE but is incorrectly accepted

- it is denoted by beta $\beta$. To control, increase sample size, improve study design, and increase effect size of the outliers.

**One-Tailed Test** - used wheen the research hypothesis specifies a direction of the effect.

**Two-Tailed Test** - used when the research hypothesis does not specify a direction of the effect but only that there is a difference.

**Introduction to DOX** - an experiment is a test or a series of tests.

**The Basic Principles of DOX** 1. Randomization, 2. Replication, 3. Blocking

**Strategy of Experiment** 1. "Best-Guess" experiment, 2. One-factor-at-a-time (OFAT) experiments, Statistically designed experiments