

Factorial ANOVA

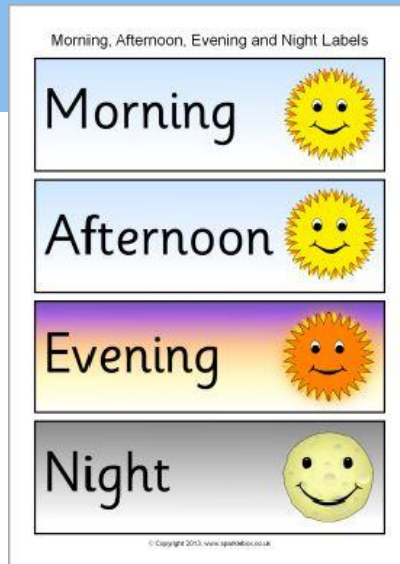
BRSM

Does time of day affect reaction time?

Independent Variables

(Factor)

Time of day



Dependent Variables

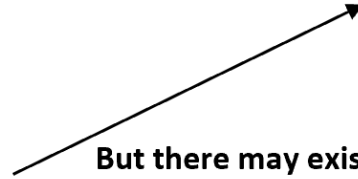
(Response)

Reaction time

Which test?

One way ANOVA

We're interested in the relationship between one or more explanatory variables and a response variable.



But there may exist some other variable (a *covariate*) that also affects the response variable.

Explanatory Variable(s)

Response Variable

Covariate

Analysis of Covariance (ANCOVA)

Independent Variables

(Factor)

Time of day

(Covariate)

Sleep
(hours slept the
night before)

Dependent Variable

(Response)

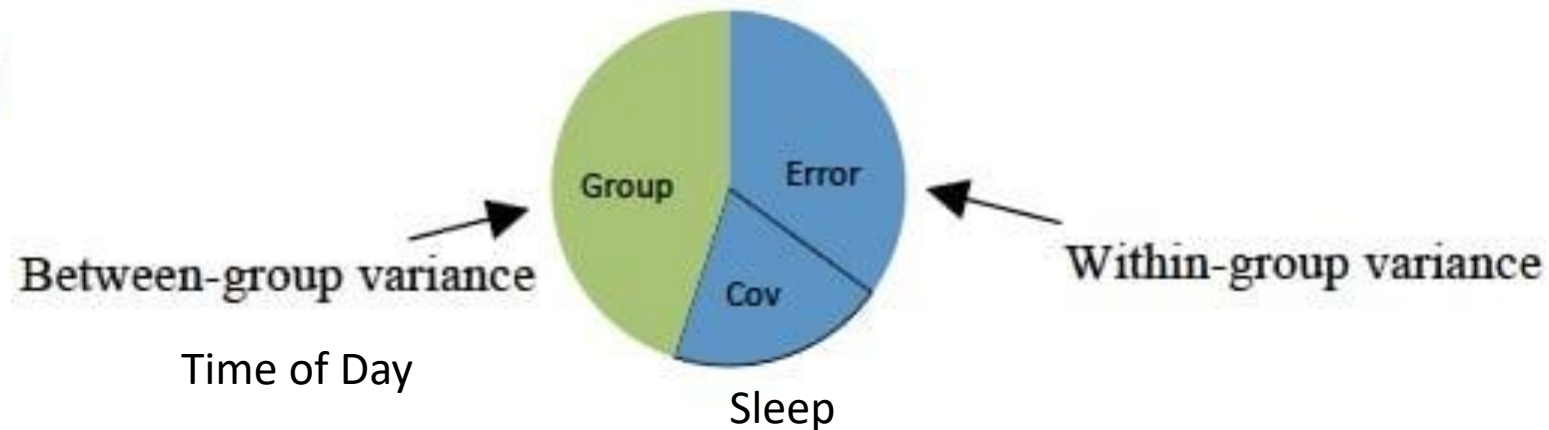
Reaction time



Advantages of ANCOVA

- **Reduces Error Variance**
 - By explaining some of the unexplained variance (SS_R) the error variance in the model can be reduced.
- **Greater Experimental Control:**
 - By holding known extraneous variables constant, we gain greater insight into the effect of the predictor variable(s).

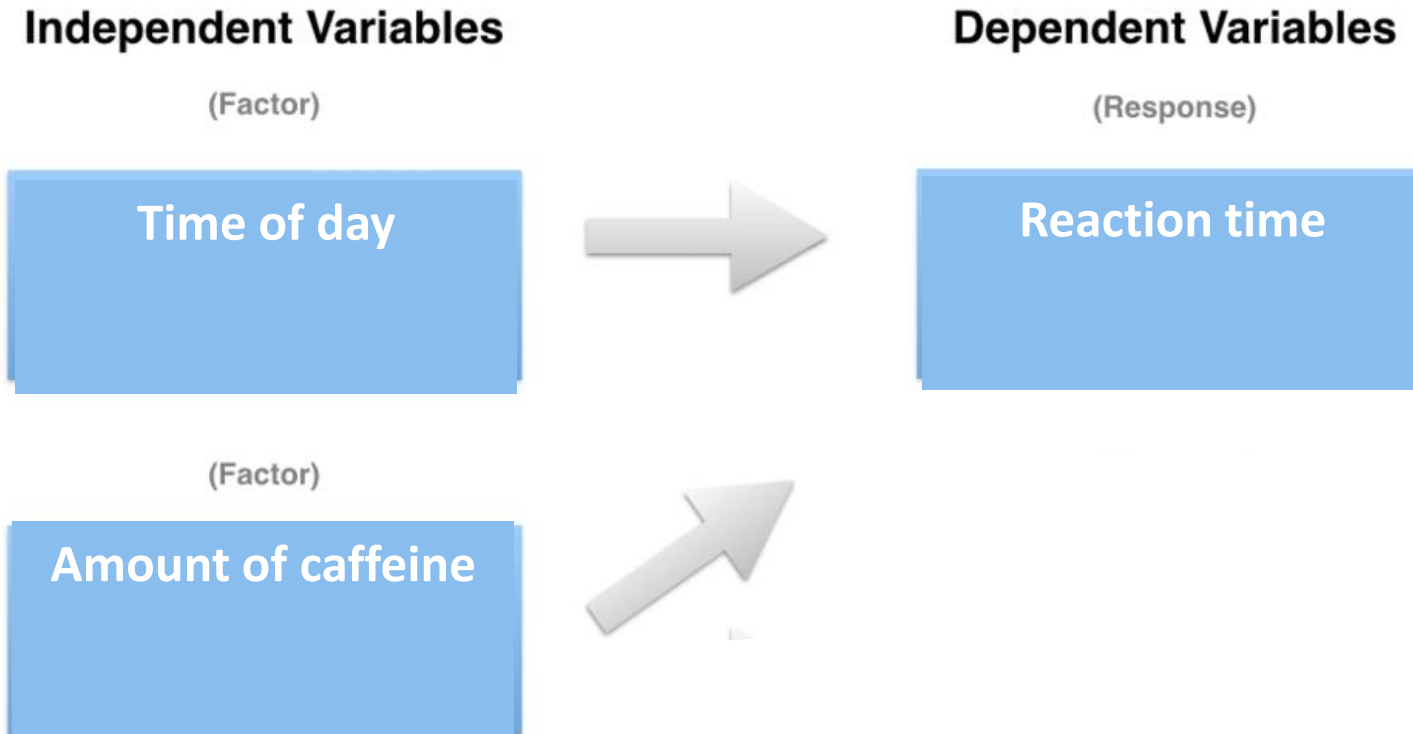
ANDY FIELD



Do people with private health insurance visit their physicians more frequently than people with no insurance or other types of insurance?

Factorial (Univariate) ANOVA

≥ 2 IVs, 1 DV



Factorial ANOVA

≥ 2 IVs, 1 DV

2x2 Design		Time of Day	
		Morning	Afternoon
Caffeine	Some Caffeine	Reaction time	Reaction time
	No Caffeine	Reaction time	Reaction time

IV – categorical

DV – continuous (interval, ratio)

2 Independent variables, 1 Dependent variable

2 x 2 ANOVA

2x3 Design		Time of Day	
		Morning	Afternoon
Caffeine	1 coffee	Reaction time	Reaction time
	2 coffees	Reaction time	Reaction time
	3 coffees	Reaction time	Reaction time

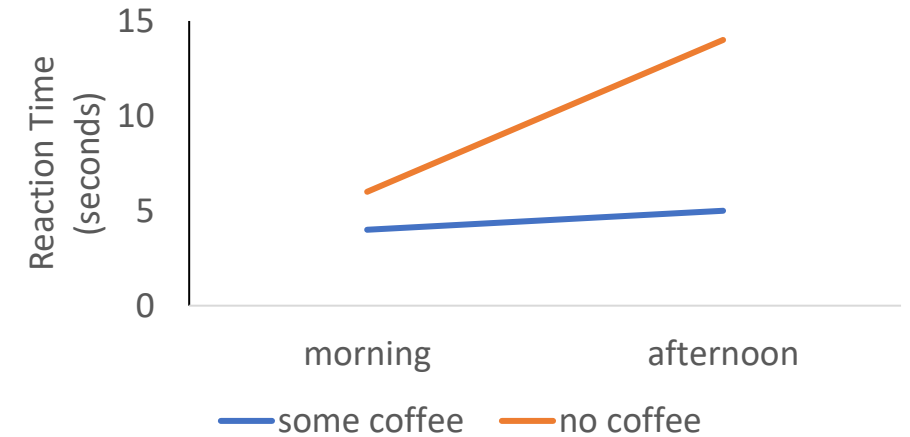
2 Independent variables, 1 Dependent variable

3 x 2 ANOVA

Factorial ANOVA

Interaction between time of day and amount of caffeine intake

2x2 Design		Time of Day	
		Morning	Afternoon
Caffeine	Some Caffeine	Reaction time	Reaction time
	No Caffeine	Reaction time	Reaction time



Source	SS	df	S^2	F
(Between) Row	$\sum [N_{\text{row}}(M_{\text{row}} - M_o)^2]$	rows-1	$\frac{SS_r}{df_r}$	$\frac{S^2_r}{S^2_w}$
(Between) Column	$\sum [N_{\text{col}}(M_{\text{col}} - M_o)^2]$	columns-1	$\frac{SS_c}{df_c}$	$\frac{S^2_c}{S^2_w}$
(Between) Interaction	$\sum [N_{\text{cell}}(M_{\text{cell}} - M_o)^2] - SS_{\text{row}} - SS_{\text{col}}$	(rows-1)(columns-1)	$\frac{SS_i}{df_i}$	$\frac{S^2_i}{S^2_w}$
Within	$\sum (X - M_{\text{cell}})^2$	N - cells	$\frac{SS_w}{df_w}$	X: individual score N: number of scores M_o : overall mean
Total	$\sum (X - M_o)^2$	N - 1		

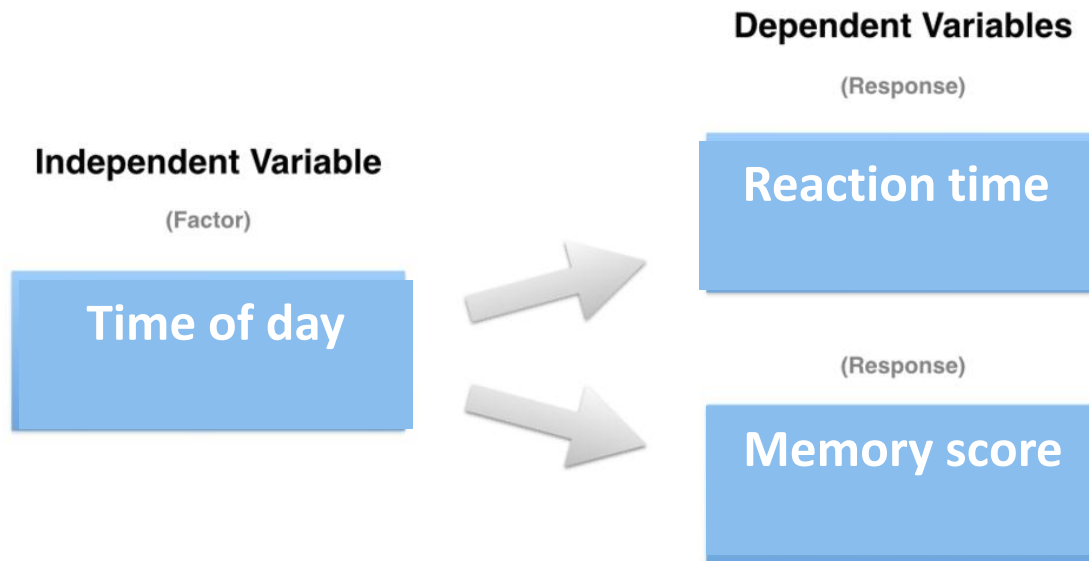
Source	SS	df	S ²	F												
(Between) Row	$\sum [N_{\text{row}}(M_{\text{row}} - M_o)^2]$	rows- 1	$\frac{SS_r}{df_r}$	$\frac{S^2_r}{S^2_w}$												
(Between) Column	$\sum [N_{\text{col}}(M_{\text{col}} - M_o)^2]$	columns-1	$\frac{SS_c}{df_c}$	$\frac{S^2_c}{S^2_w}$												
(Between) Inter-action	$\sum [N_{\text{cell}}(M_{\text{cell}} - M_o)^2] - SS_{\text{row}} - SS_{\text{col}}$	(rows- 1) (columns-1)	$\frac{SS_i}{df_i}$	$\frac{S^2_i}{S^2_w}$												
Within	<div>MEANS:</div> <table><tr><td></td><td>Col A</td><td>Col B</td><td>Row Means</td></tr><tr><td>Row A</td><td>Cell</td><td>Cell</td><td>→</td></tr><tr><td>Row B</td><td>Cell</td><td>Cell</td><td>→</td></tr></table> <div>Column Means</div>				Col A	Col B	Row Means	Row A	Cell	Cell	→	Row B	Cell	Cell	→	X: individual score N: number of scores M _o : overall mean
	Col A	Col B	Row Means													
Row A	Cell	Cell	→													
Row B	Cell	Cell	→													
Total																

Multivariate ANOVA (MANOVA)

≥ 2 DVs

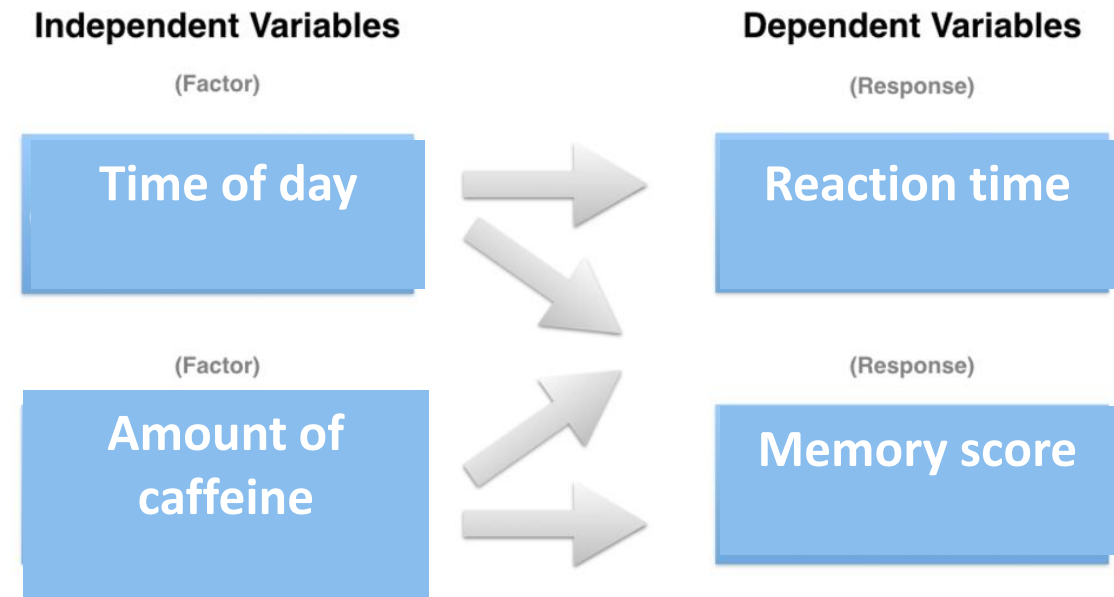
1 IV + 2 DVs

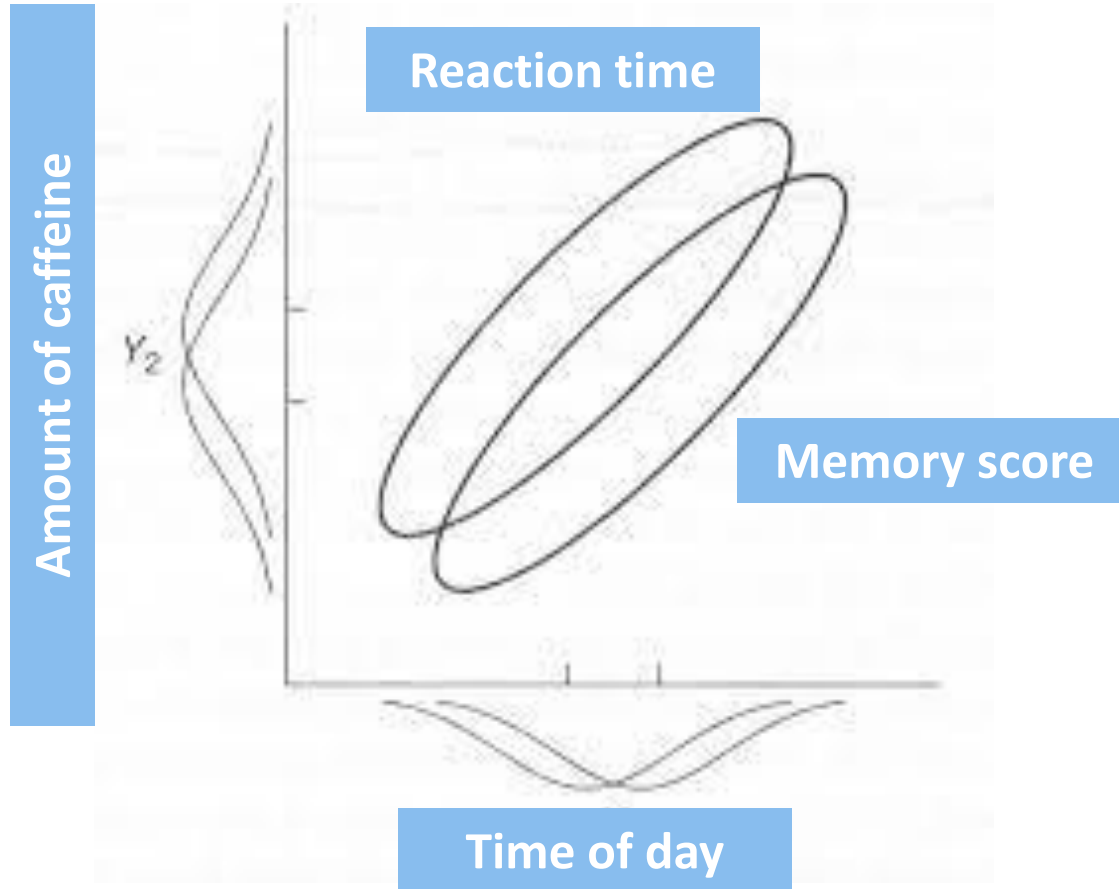
ONE-WAY MANOVA EXAMPLE



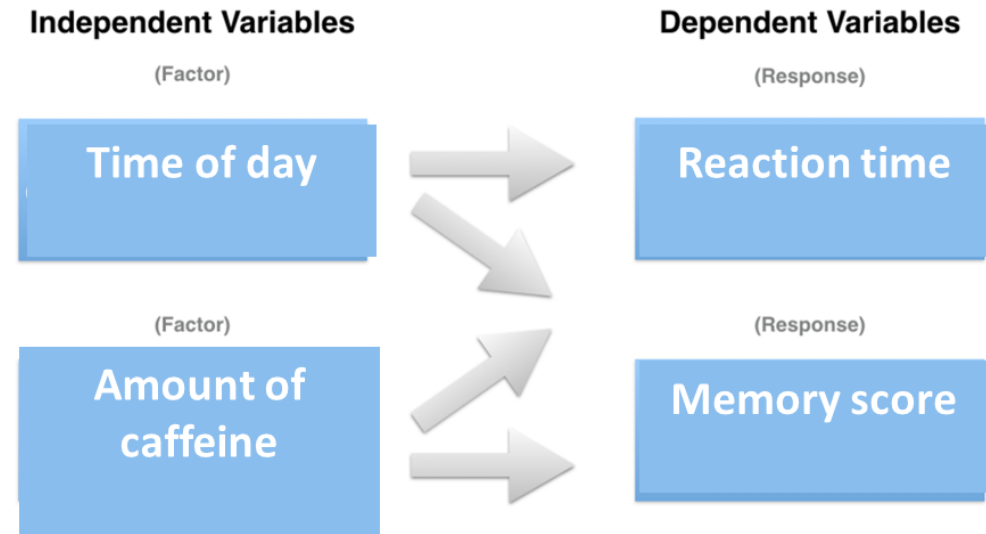
2 IVs + 2 DVs

TWO-WAY MANOVA EXAMPLE





TWO-WAY MANOVA EXAMPLE



Main effect - Time of Day?

Main effect - Amount of Caffeine?

Interaction? – MANOVA brings out interaction effects

linear combination of DVs to increase effects of IVs

Is MANOVA different from Repeated measures?

- Multiple DVs but not related
- They could be correlated/covariate

(Homogeneity of Covariances)

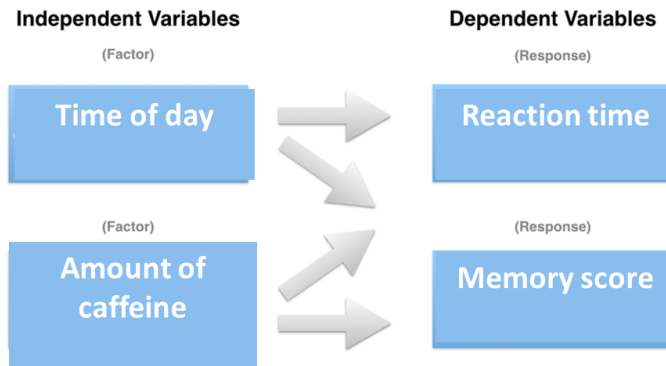
homogeneous variance → Pillai's trace test statistic

Non-homogenous variance → Wilks' lambda test statistic

Assumption of sphericity

- Same participant is repeated tested
- Relationship between multiple timepoints of DV
- Sphericity assumes these timepoints are homogenous
- Individual differences are removed

TWO-WAY MANOVA EXAMPLE



Reaction time → coffee → reaction time

Spot the difference

Younger vs older adults



Spot the difference

Younger vs older adults

Effect of distraction?



Spot the difference

Younger vs older adults

Effect of distraction?

IV 1 – age (young, old)

IV 2 – no distraction, unpleasant sounds

DV – no. of differences spotted (attention)



Spot the difference

Younger vs older adults

Effect of distraction?

Effect of reward?



Spot the difference

Younger vs older adults

Effect of distraction?

IV 1 – age (young, old)

IV 2 – no distraction, unpleasant sounds

DV – no. of differences spotted

Effect of reward?

IV 3– no reward, low reward, high reward



Spot the difference

Younger vs older adults

Effect of distraction?

Can reward change attention levels in distractive environments?



Effect of distraction?

IV 1 – age (young, old)

IV 2 – no distraction, unpleasant sounds

DV – no. of differences spotted

Can reward change attention in
distractive environments?

Spot the difference

Younger vs older adults



Old

Young

Attention → no reward → attention → reward → attention

distraction

no distraction

- Scenario 1: A fitness instructor wants to test the effectiveness of a performance-enhancing herbal supplement on students in his exercise class. The instructor gives Group A The herbal supplement and Group B receives the placebo. The students' fitness level is compared before and after six weeks of consuming the supplement or the sugar pill. His data do not support his hypothesis that the herbal supplement had an effect on fitness levels.

- Scenario 2: A social psychologist is interested discovering if whether women who are taller have a stronger career orientation. She measures height and gives a survey to women that measures many personality variables, including career orientation. Her data support her hypothesis that women who are taller had stronger career orientations.

Several weeks after Allen conducted a classroom experiment on the effectiveness of various metals in releasing hydrogen gas from hydrochloric acid, he read that the gas company was burying sheets of magnesium next to iron pipelines in order to prevent rusting. Allen wondered if other active metals would also be effective in preventing rust.

To investigate, he placed each of the following into a separate test tube containing water: one iron nail; one iron nail wrapped with an aluminum strip; one iron nail wrapped with a magnesium strip; and one iron nail wrapped in a lead strip. He used the same amounts of water from the same source, equal amounts of the metal wraps and the same type of iron nails. At the end of five days, he described the amounts of rusting either as small, moderate or large. He also recorded the color of the water.

Class Data	Gender	Years spent at IIIT (including covid years)	How stressful has the semester been for you?	Do you engage in physical/sports activities everyday?	How many hours do you spend listening to music every day?	In the past week, how many hours (avg) have you slept every night ?
	female	4	5	yes	0.5	5
	male	4	5	no	4	4.5
	male	1.5	3	yes	4	7
	male	3	3	yes	2	8
	male	1.5	4	not everyday, sometimes	0	6
	male	2.5	3	yes	1	7
	female	4	5	yes	1	7
	female	5	3	not everyday, sometimes	2	7
	male	5.5	4	not everyday, sometimes	2	7
	male	0.5	5	not everyday, sometimes	0	4
	male	1	3	not everyday, sometimes	4	7
	male	0.5	4	yes	2	5
	male	3	3	yes	1	7
	female	4	2	not everyday, sometimes	0.5	6
	female	1	4	yes	1	6
	male	3.5	1	no	0	6.5
	male	3	4	yes	2	8
	female	3	3	yes	2	6
	male	1.5	2	not everyday, sometimes	0	5
	male	0	4	yes	0.5	8
	non-binary	4	4	not everyday, sometimes	2	7
	male	1.5	4	not everyday, sometimes	1	6

- Q1. Do students listen to more music after 2 years in IIIT?
- Q2. Does exercise affect night sleep?
- Q3. Which factors predict the stress experienced by students at IIIT?

		IV – categorical	DV – continuous (interval, ratio)
		Independent factor 1 IV > 2 groups	Dependent (Related) Samples 1 DV > 2 timepoints
Parametric (normal)	Homogeneous	One way ANOVA	Repeated measures ANOVA
	Non homogenous	Welch ANOVA	Sphericity correction
Non-parametric		<i>Kruskal-Wallis ANOVA</i>	Friedman's ANOVA

	>=2 IVs & 1 DV	>=1 IV, repeated DV	>=1 IV & >= 2 DVs
	Factorial ANOVA	Mixed ANOVA (>1 factors + Repeated measures)	MANOVA

IV= factor (these terms are used interchangeably)

VariableX	VariableY	Type of correlation
Nominal	Nominal	Phi coefficient
Nominal	Ordinal	Rank-biserial coefficient
Nominal	Interval	Point-biserial
Ordinal	Ordinal	Spearman rank correlation coefficient
Interval	Interval	Pearson product-moment correlation coefficient

Test type	Between subjects designs (Independent samples)	Within subject designs (repeated measures/ matched pairs)
Non-parametric (for categorical data)	Chi-square test	The binomial sign test
Non-parametric (for ordinal data)	Mann-Whitney U	Wilcoxon Signed-Rank Test The binomial sign test
Parametric	Unrelated t-test (level of data: interval)	Related t-test (level of data: interval)

IV – categorical

DV – continuous (interval, ratio)

		Independent factor	Dependent (Related) Samples
		1 IV	1 DV
		> 2 groups	> 2 timepoints
Parametric (normal)	Homogeneous	One way ANOVA	Repeated measures ANOVA
	Non homogenous	Welch ANOVA	Sphericity correction
Non-parametric		Kruskal-Wallis ANOVA	Friedman’s ANOVA

	>=2 IVs & 1 DV	>=1 IV, repeated DV	>=1 IV & >= 2 DVs
	Factorial ANOVA	Mixed ANOVA (Factors + Repeated measures)	MANOVA