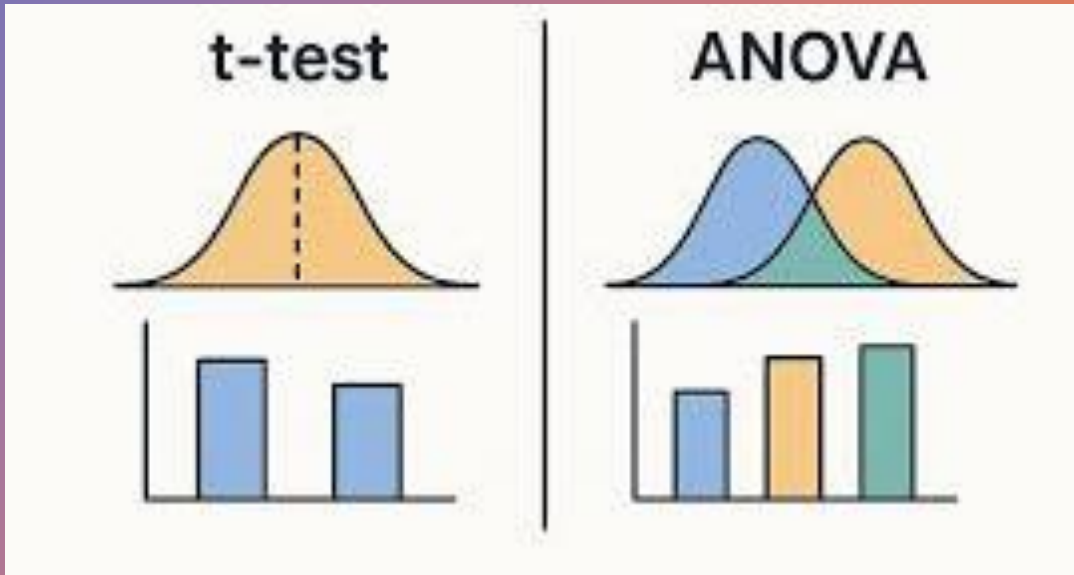




LCDB7011

Quantitative Research Methods

- Week 8&9
- T-test and ANOVA
- Dr. Helen LEE



Agenda of the lecture

i. T test

- Independent sample t test
- One way sample t test

ii. ANOVA

- One-way ANOVA
- Two-way ANOVA



Independent Samples t Test

Independent Samples t Test

- The Independent Samples t Test compares the means of two independent (separate) groups to find out if the associated population means are statistically significantly different.
- This involves two variables. The variable being tested (test variable or dependant variable) and the grouping variable (independent variable)
- If you want to know how the maths works, have a look here:

[T-test formula](#) – look at the independent samples test.



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Independent Samples t Test - Assumptions

- Independent sample (Between-subjects)
- Dependent (test) variable that is continuous (i.e., interval or ratio level)
- Independent variable that is categorical (i.e., two or more groups)
- Independent samples/groups – no relationship between the subjects in both Random sample of data from the population
- Normal distribution (approximately) of the dependent variable for each group, although this is less important with larger samples
- Homogeneity of variances (i.e., variances approximately equal across groups)
- No outliers
- When one or more of the assumptions for the Independent Samples t Test are not met, you may want to run the nonparametric Mann-Whitney U Test instead

From: <https://libguides.library.kent.edu/SPSS/IndependentTTest>



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Independent Samples t Test

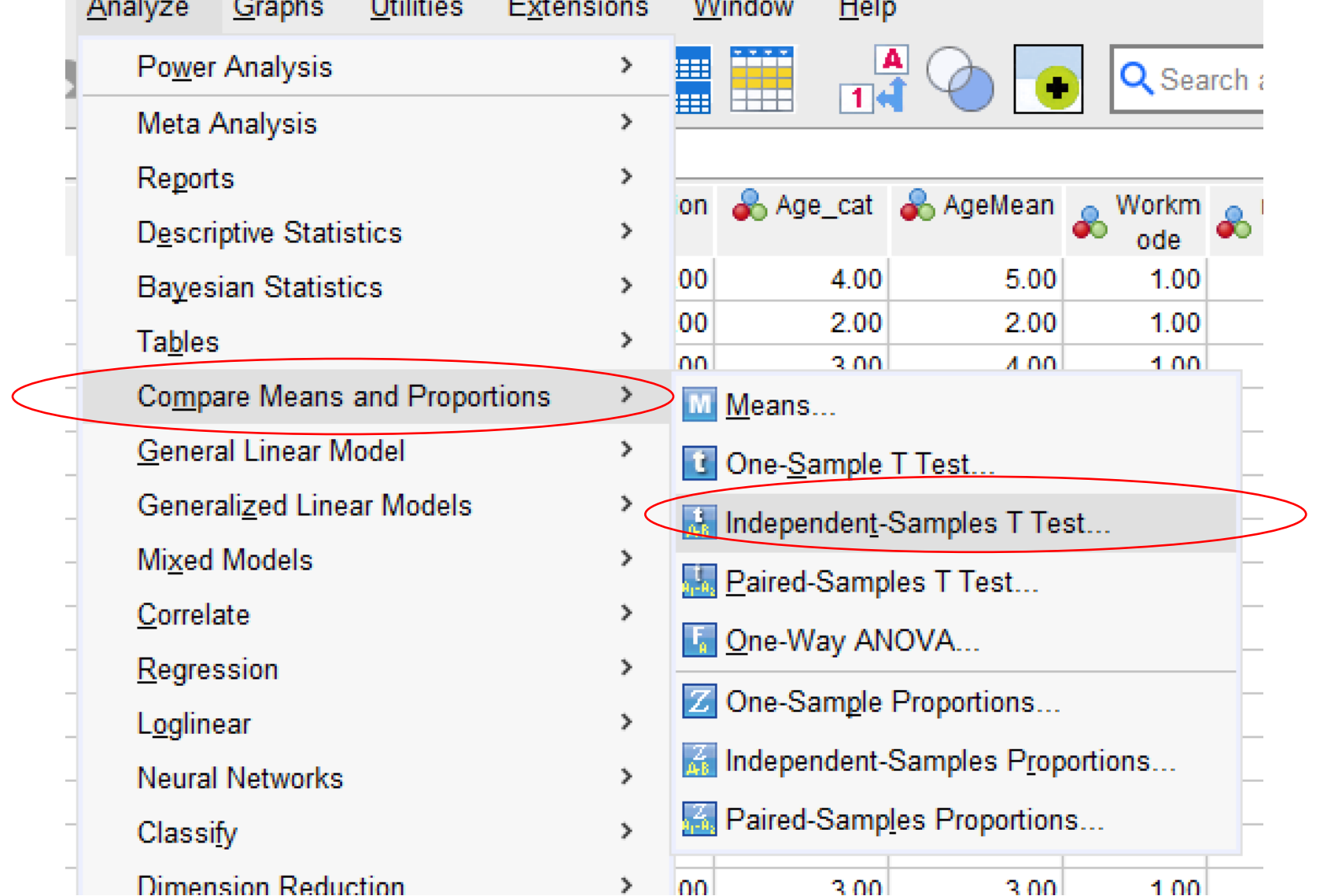
H0 : No difference in job satisfaction between male and female

H1 : There was difference in job satisfaction between male and female

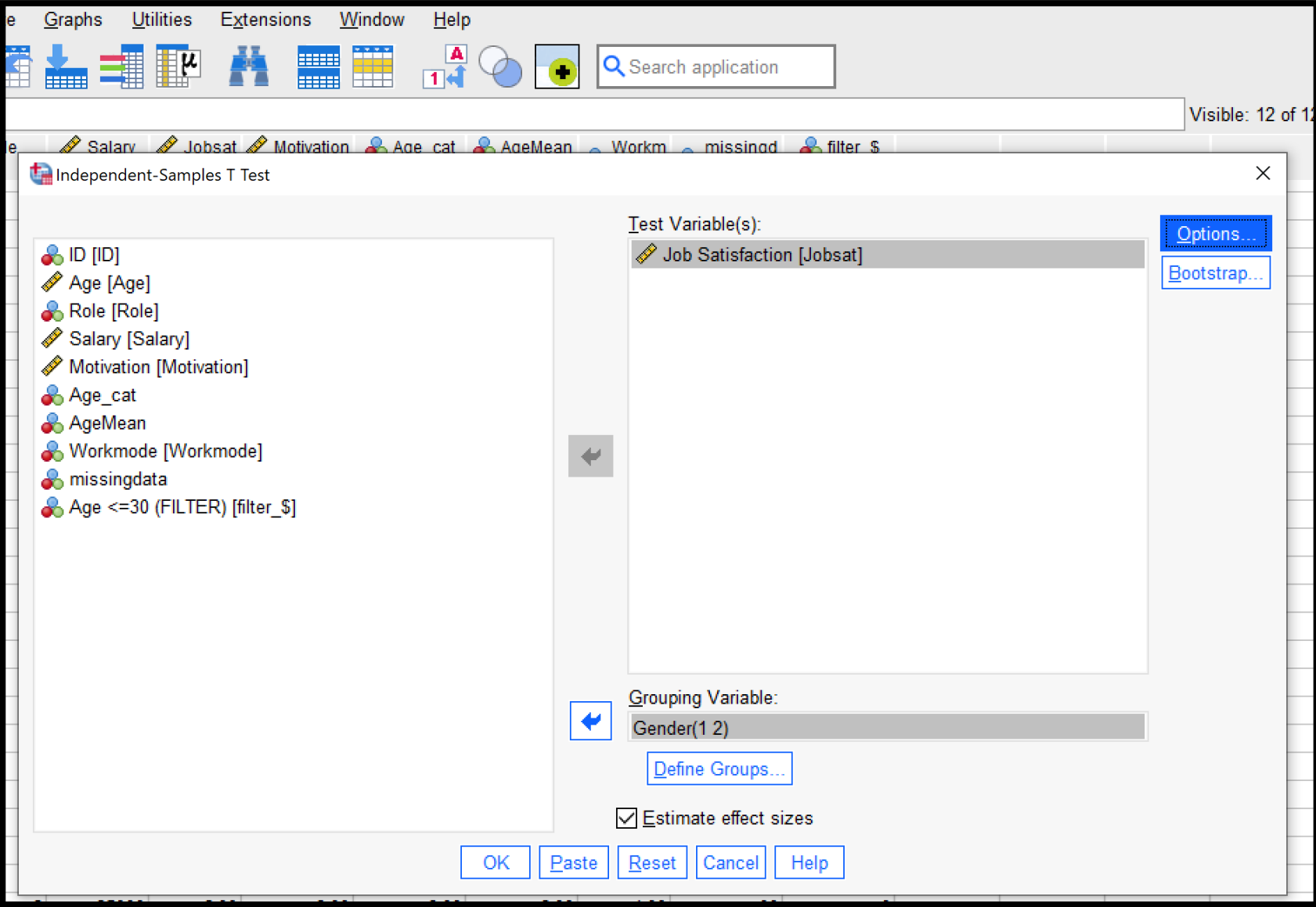


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Independent Samples t Test



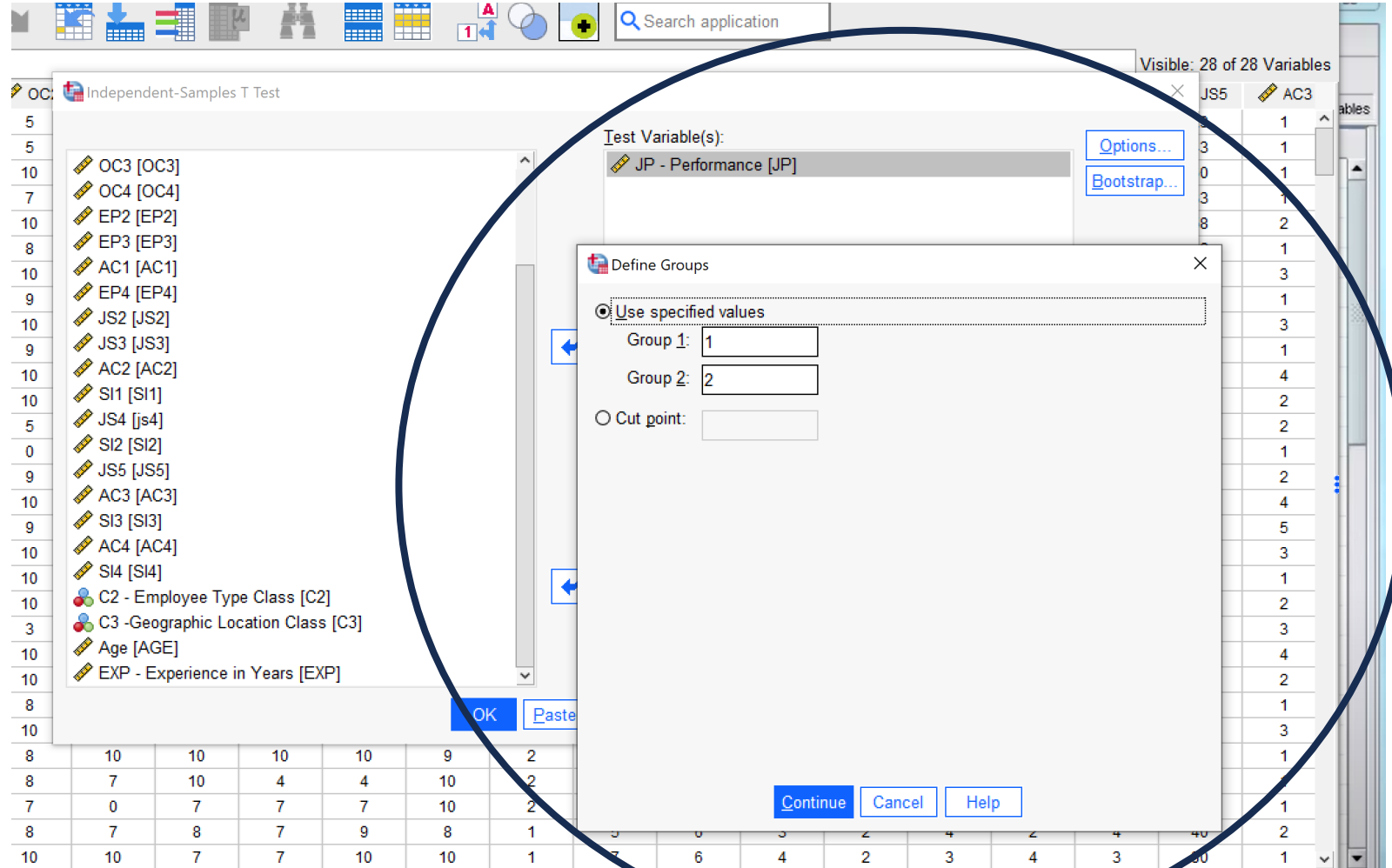
Independent Samples *t* Test



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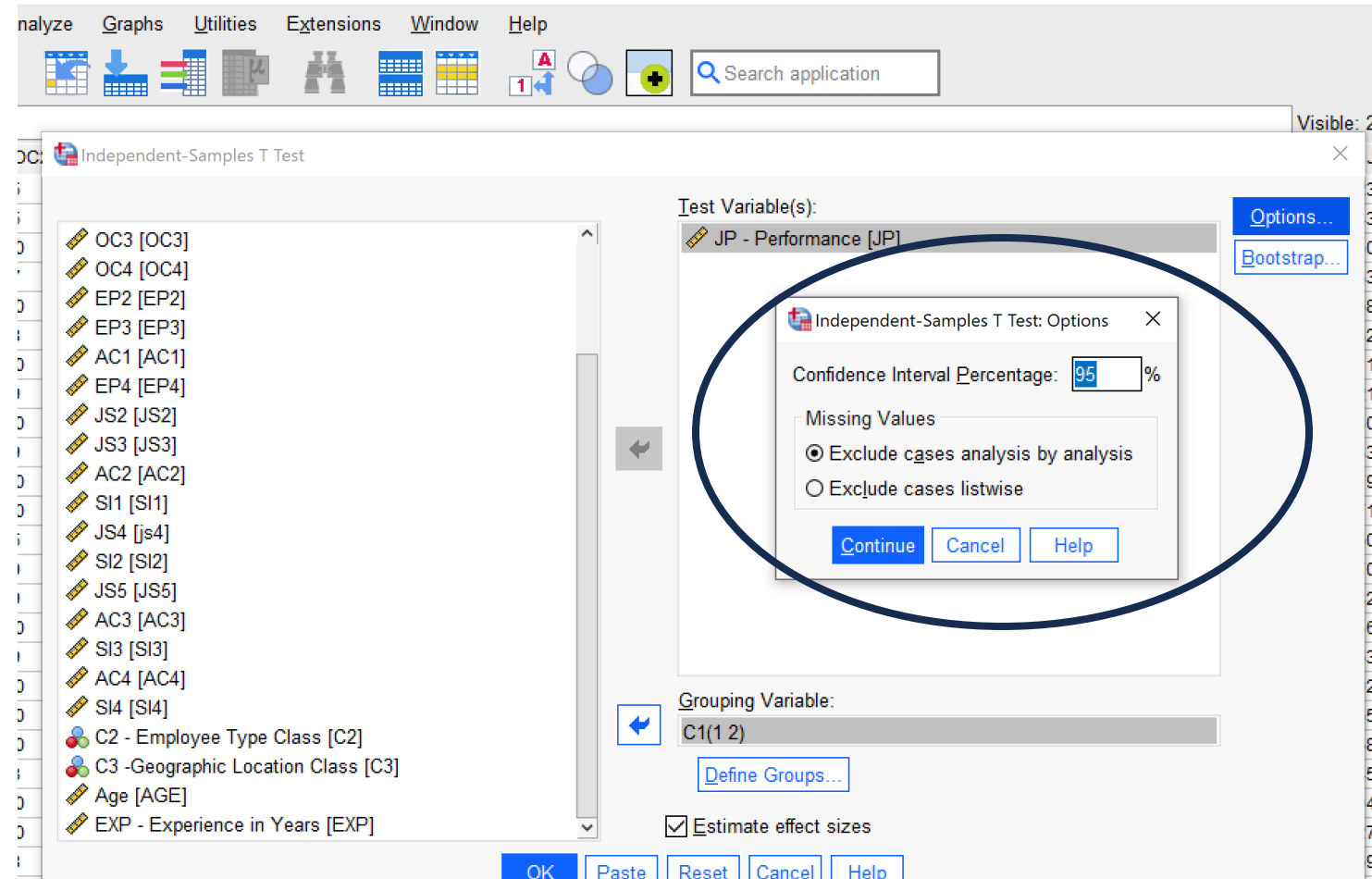
Independent Samples t Test

Define Group



Independent Samples t Test

Significant
Level



Independent Samples *t* Test

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Job Satisfaction	Male	39	3.0256	1.06344	.17029
	Female	19	2.5263	.84119	.19298

P > .05
Then, accept H0
Equal Variance assumed

P < .05
Then, reject H0
Significant difference

Across 0
NOT Significantly different

Independent Samples

		Levene's Test for Equality of Variances						t-test for Equality of Means				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference			Lower	Upper
Job Satisfaction	Equal variances assumed	.819	.369	1.789	56	.039	.079	.49933	.27905			-.05968	1.05833
	Equal variances not assumed			1.940	44.239	.029	.059	.49933	.25737			-.01929	1.01794

Independent Samples Effect Sizes

		Standardizer ^a	Point Estimate	95% Confidence Interval	
Job Satisfaction	Cohen's d	.99742	.501	-.058	1.055
	Hedges' correction	1.01103	.494	-.057	1.040
	Glass's delta	.84119	.594	.005	1.167

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control (i.e., the second) group.



Presentation of Independent Sample T-Test results

For Insignificant Results

- An independent-samples t-test was conducted to compare the **[Add Criterion Variable Here]** for **[Group1]** and **[Group 2]**. There were [no] significant differences (t (df) = _____, p = _____) in scores for **[Group1]** (M = _____, SD = _____) and **[Group 2]** (M = _____, SD = _____). The magnitude of the differences in the means (mean difference = _____, 95% CI: _____ to _____) was very small. Hence, H1 was not supported.

For Significant Results

- An independent-samples t-test was conducted to compare the **[Add Criterion Variable Here]** for **[Group1]** and **[Group 2]**. There were significant differences (t (df) = _____, p = _____) in the scores with mean score for **[Group1]** (M = _____, SD = _____) was higher/lower than and **[Group 2]** (M = _____, SD = _____). The magnitude of the differences in the means (mean difference = _____, 95% CI: _____ to _____) was significant. Hence, H1 was supported.



Independent Samples t Test

- An independent T-test was conducted to compare the job satisfaction for male (Group1) and female (Group 2). There were significant differences ($t(df) = 56, p = .039$ in the scores with the mean score for Male (Group 1) $M = 3.026, SD = 1.06$ was higher than the mean score for female (Group 2), $M = 2.53, SD = .84$. The magnitude of the difference in the means (mean difference = .499, 95% CI = .60 to 1.06) was significant. Hence, H_1 was supported



Samples t Test

Compared with the average mean



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Samples t Test

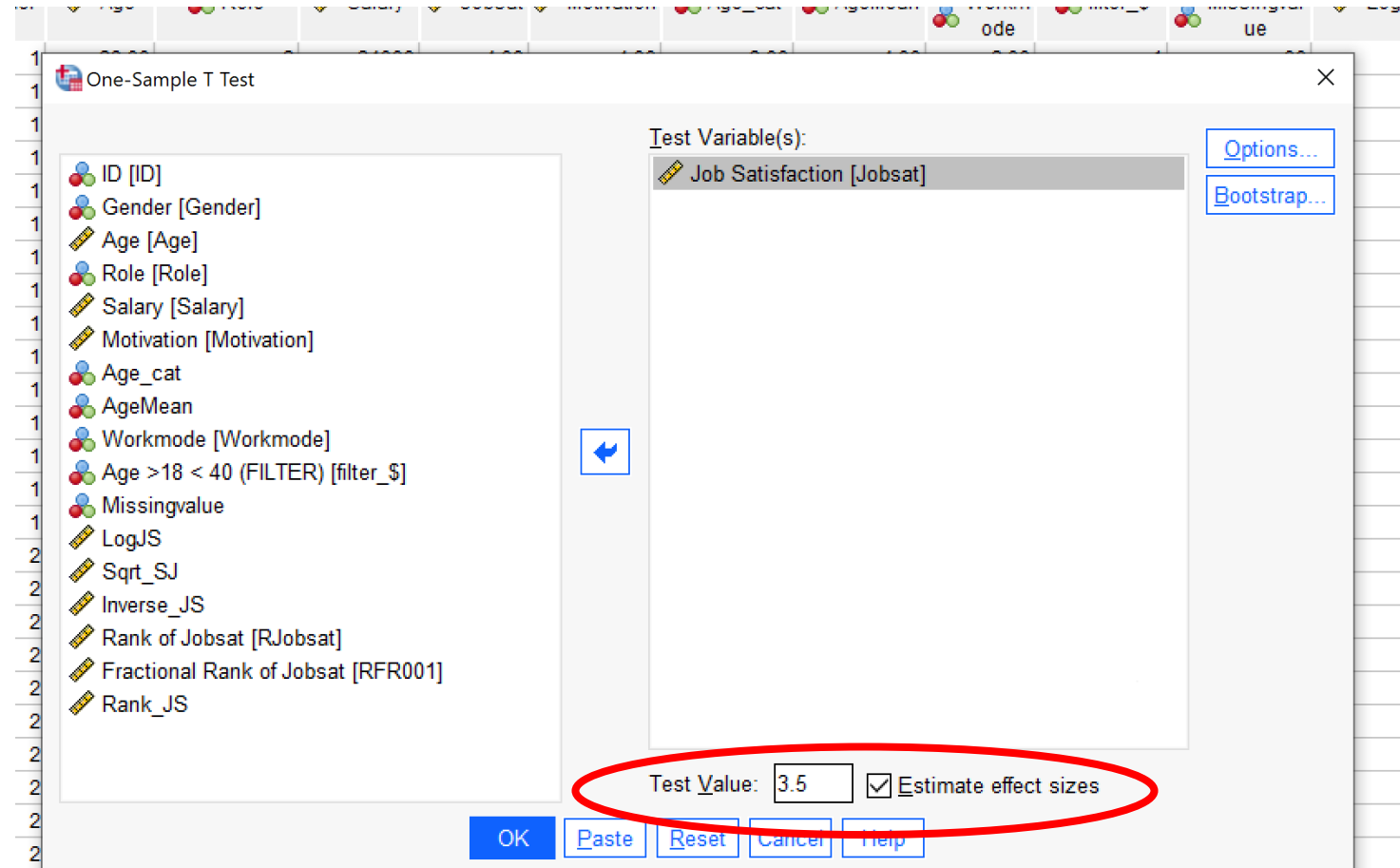
test for normality_bocases_v1.sav [Dataset] - IBM SPSS Statistics Data Editor

The screenshot shows the IBM SPSS Statistics Data Editor interface. The 'Analyze' menu is open, and the 'Compare Means and Proportions' option is selected, which has opened a sub-menu. The sub-menu contains the following options: 'Means...', 'One-Sample T Test...', 'Independent-Samples T Test...', 'Paired-Samples T Test...', 'One-Way ANOVA...', 'One-Sample Proportions...', 'Independent-Samples Proportions...', and 'Paired-Samples Proportions...'. The 'One-Sample T Test...' option is highlighted. In the background, a data table is visible with columns: ID, Gender, Age, Age_cat, AgeMean, Workmode, filter_\$, Missingvalue, and Location. The data table contains 19 rows of data.

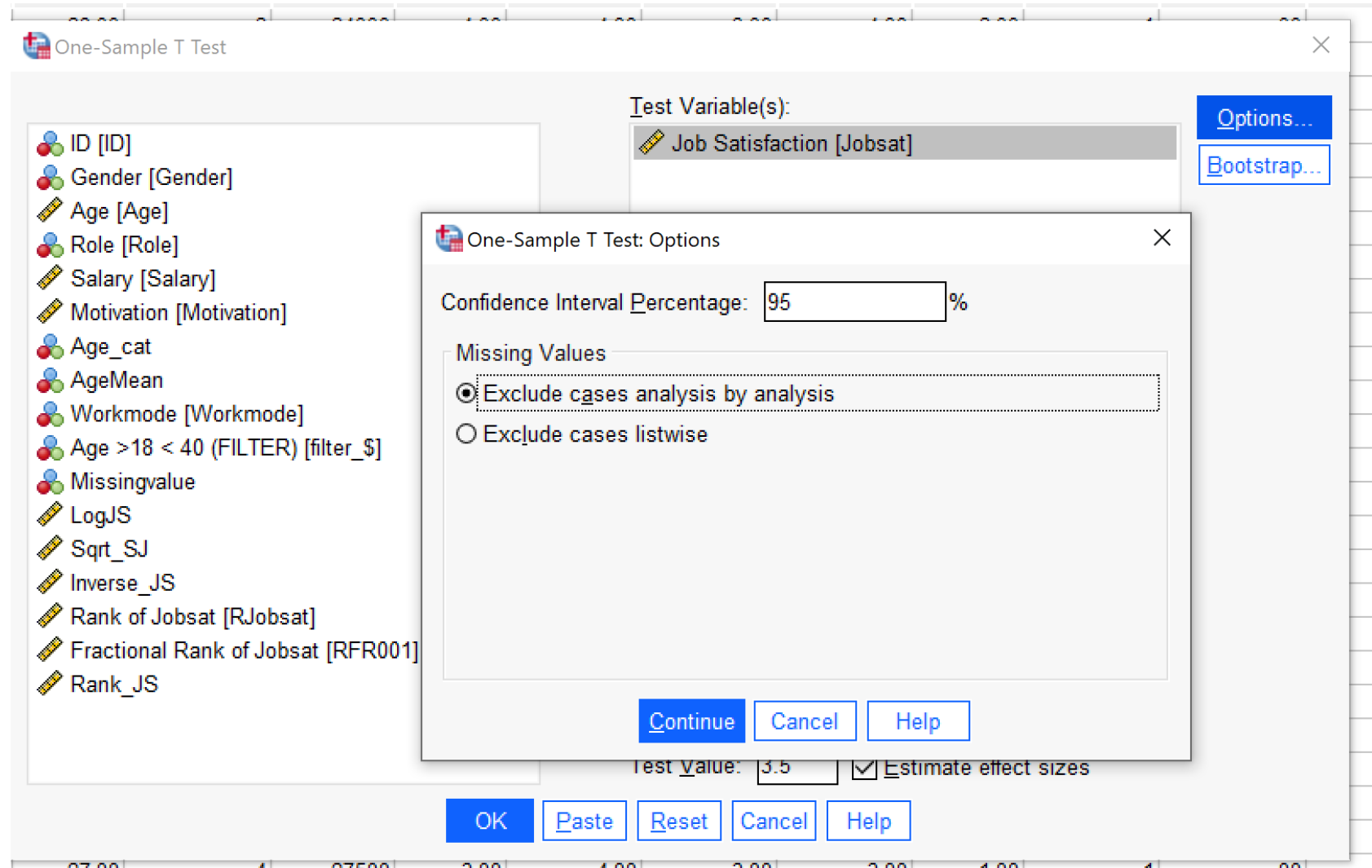
ID	Gender	Age	Age_cat	AgeMean	Workmode	filter_\$	Missingvalue	Location
40	1	18.00	1.00	2.00	1.00	1	.00	
41	1	18.00	1.00	2.00	1.00	1	.00	
42	1	18.00	1.00	2.00	1.00	1	.00	
43	2	23.00	1.00	2.00	1.00	1	.00	
44	2	45.00	1.00	2.00	1.00	1	.00	
45	2	63.00	1.00	2.00	1.00	1	.00	
46	2	55.00	1.00	2.00	1.00	1	.00	
47	2	26.00	1.00	2.00	1.00	1	.00	
48	2	30.00	1.00	2.00	1.00	1	.00	
49	2	42.00	1.00	2.00	1.00	1	.00	
50	2	27.00	1.00	2.00	1.00	1	.00	
51	2	37.00	1.00	2.00	1.00	1	.00	
52	2	42.00	1.00	2.00	1.00	1	.00	
53	2	27.00	1.00	2.00	1.00	1	.00	
54	2	37.00	1.00	2.00	1.00	1	.00	
55	2	27.00	1.00	2.00	1.00	1	.00	
56	2	37.00	1.00	2.00	1.00	1	.00	
57	2	42.00	1.00	2.00	1.00	1	.00	
58	2	27.00	1.00	2.00	1.00	1	.00	

Samples t Test

Assume the average
satisfaction mean = 3.5



Samples t Test



Independent Samples *t* Test

T-Test

One-Sample Statistics



	N	Mean	Std. Deviation	Std. Error Mean
Job Satisfaction	58	2.8621	1.01650	.13347

Degree of freedom

$$df = N - 1$$

$$\Rightarrow 58 - 1 = 57$$

One-Sample Test

Test Value = 3.5

	t	df	Significance		Mean Difference	95% Confidence Interval of the Difference	
			One-Sided p	Two-Sided p		Lower	Upper
Job Satisfaction	-4.779	57	<.001	<.001	-.63793	-.9052	-.3707

One-Sample Effect Sizes

		Standardizer ^a	Point Estimate	95% Confidence Interval	
Job Satisfaction	Cohen's d	1.01650	-.628	-.907	-.343
	Hedges' correction	1.03012	-.619	-.895	-.339

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

Sample t-test

- 3 ways of measuring the mean statistical difference in SPSS
 - i. t-value (from t table)
 - ii. p-value < 0.05
 - iii. Confidence Interval

Samples t Test

T-Test

1. t-table
If t value $>$ critical value, then it is statistically different.

One-Sample Statistics



	N	Mean	Std. Deviation	Std. Error Mean
Job Satisfaction	58	2.8621	1.01650	.13347

One-Sample Test

Test Value = 3.5

	t	df	Significance		Mean Difference	95% Confidence Interval of the Difference	
			One-Sided p	Two-Sided p		Lower	Upper
Job Satisfaction	-4.779	57	<.001	<.001	-.63793	-.9052	-.3707

One-Sample Effect Sizes

				95% Confidence Interval		
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a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

Critical values of t for two-tailed tests

Significance level (α)

Degrees of freedom (df)	.2	.15	.1	.05	.025	.01	.005	.001
1	3.078	4.165	6.314	12.706	25.452	63.657	127.321	636.619
2	1.886	2.282	2.920	4.303	6.205	9.925	14.089	31.599
3	1.638	1.924	2.353	3.182	4.177	5.841	7.453	12.924
4	1.533	1.778	2.132	2.776	3.495	4.604	5.598	8.610
5	1.476	1.699	2.015	2.571	3.163			
6	1.440	1.650	1.943	2.447	2.969			
7	1.415	1.617	1.895	2.365	2.841			
8	1.397	1.592	1.860	2.306	2.752			
9	1.383	1.574	1.833	2.262	2.685			
10	1.372	1.559	1.812	2.228	2.634			
11	1.363	1.548	1.796	2.201	2.593			
12	1.356	1.538	1.782	2.179	2.560			
13	1.350	1.530	1.771	2.160	2.533			
14	1.345	1.523	1.761	2.145	2.510			
15	1.341	1.517	1.753	2.131	2.490			
16	1.337	1.512	1.746	2.120	2.473			
17	1.333	1.508	1.740	2.110	2.458			
18	1.330	1.504	1.734	2.101	2.445			
19	1.328	1.500	1.729	2.093	2.433			

Critical values
P value = 0.05
df = 57
CV = 2.009

24	1.318	1.487	1.711	2.064	2.391	2.797	3.091	3.745
25	1.316	1.485	1.708	2.060	2.385	2.787	3.078	3.725
26	1.315	1.483	1.706	2.056	2.379	2.779	3.067	3.707
27	1.314	1.482	1.703	2.052	2.373	2.771	3.057	3.690
28	1.313	1.480	1.701	2.048	2.368	2.763	3.047	3.674
29	1.311	1.479	1.699	2.045	2.364	2.756	3.038	3.659
30	1.310	1.477	1.697	2.042	2.360	2.750	3.030	3.646
40	1.303	1.468	1.684	2.021	2.329	2.704	2.971	3.551
50	1.299	1.462	1.676	2.009	2.311	2.678	2.937	3.496
60	1.296	1.458	1.671	2.000	2.299	2.660	2.915	3.460
70	1.294	1.456	1.667	1.994	2.291	2.648	2.899	3.435
80	1.292	1.453	1.664	1.990	2.284	2.639	2.887	3.416
100	1.290	1.451	1.660	1.984	2.276	2.626	2.871	3.390
1000	1.282	1.441	1.646	1.962	2.245	2.581	2.813	3.300
Infinite	1.282	1.440	1.645	1.960	2.241	2.576	2.807	3.291

<file:///C:/Users/h.lee/OneDrive%20-%20University%20of%20Wales%20Trinity%20Saint%20David/Documents/Business%20Team/DBA%20Programme/Quants Research%20methods/Uploaded%20to%20Moodle/Students-t-table-one-tailed-two-tailed Table.pdf>

Samples *t* Test

T-Test

2. P value
If $p \text{ value} < 0.05$, then it is statistically different.

One-Sample Statistics



	N	Mean	Std. Deviation	Std. Error Mean
Job Satisfaction	58	2.8621	1.01650	.13347

One-Sample Test

Test Value = 3.5

	t	df	Significance		Mean Difference	95% Confidence Interval of the Difference	
			One-Sided p	Two-Sided p		Lower	Upper
Job Satisfaction	-4.779	57	<.001	<.001	-.63793	-.9052	-.3707

One-Sample Effect Sizes

		Standardizer ^a	Point Estimate	95% Confidence Interval	
Job Satisfaction	Cohen's d			Lower	Upper
	Hedges' correction	1.01650	-.628	-.907	-.343
		1.03012	-.619	-.895	-.339

a. The denominator used in estimating the effect sizes.

Cohen's d uses the sample standard deviation.

Hedges' correction uses the sample standard deviation, plus a correction factor.

Samples t Test

T-Test

3. Confidence Interval (95%)
If Confident Interval contain 0, then
the mean is not statistically different

One-Sample Statistics



	N	Mean	Std. Deviation	Std. Error Mean
Job Satisfaction	58	2.8621	1.01650	.13347

One-Sample Test

Test Value = 3.5

	t	df	Significance		Mean Difference	95% Confidence Interval of the Difference	
			One-Sided p	Two-Sided p		Lower	Upper
Job Satisfaction	-4.779	57	<.001	<.001	-.63793	-.9052	-.3707

One-Sample Effect Sizes

				95% Confidence Interval		
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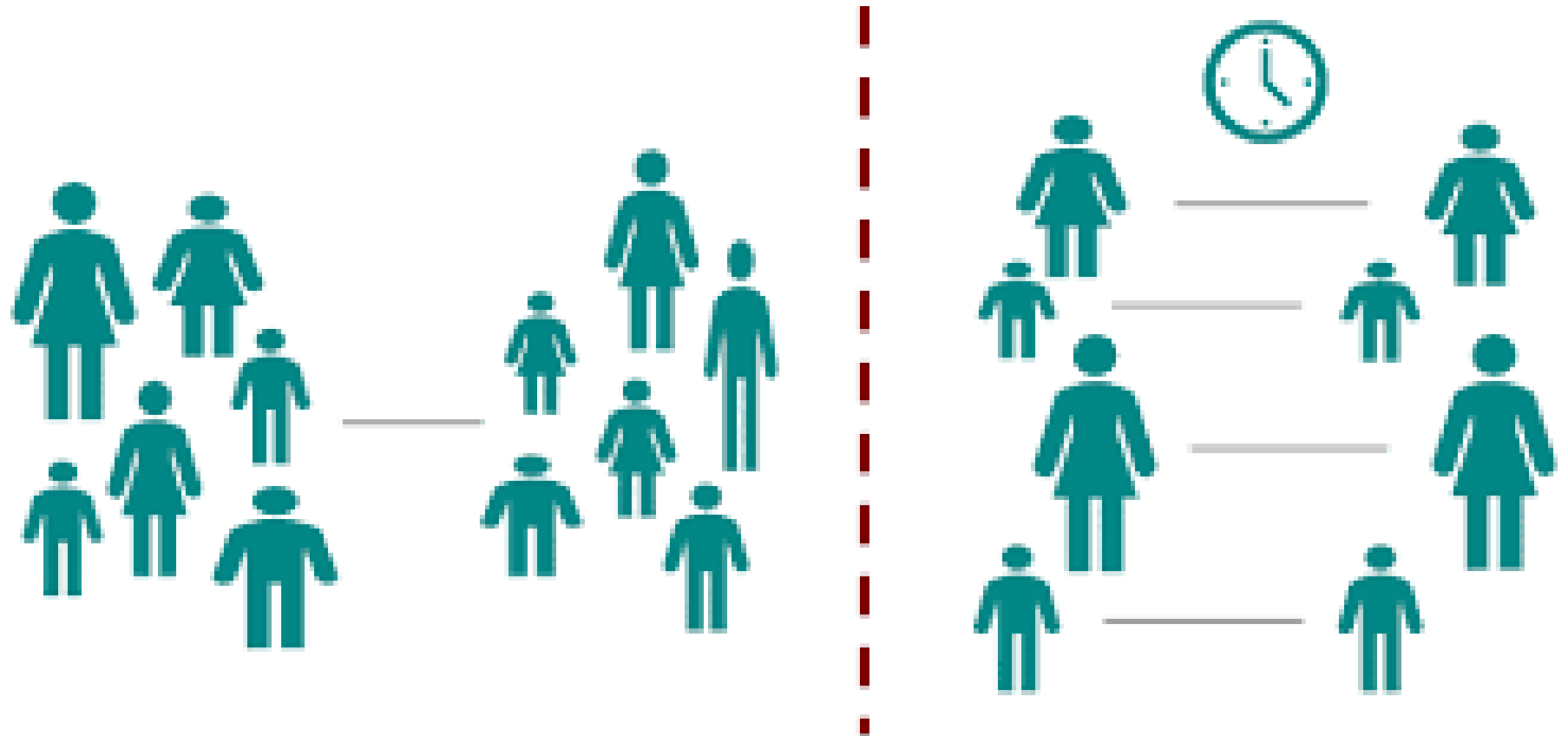
Samples *t* Test

Reporting One Sample T-Test in APA Style

A one sample *t*-test was run to determine whether the weight of Catfish was different to normal, defined as a weight of 112kg. Mean weight (120.4 ± 10.46) was higher than the normal average weight measurement of 112kg, a statistically significant difference of 8.40 (95% CI, 0.92 to 15.88), $t(9) = 2.540$, $p = 0.032$.

There was a statistically significant difference between means ($p < .05$). Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Paired Sample t Test



Paired Sample t Test - Assumptions

1. There are two dependent groups or samples
e.g. The weight of one and the same person is measured before and after a diet.
2. The variables are interval scaled
 - The salary of a person
3. The differences of the paired values are normally distributed.

Paired-samples t Test

- Dependent sample (Within-subjects)
- Use a paired t -test when each subject has a pair of measurements, such as a before and after score.

In-class activity

Please use the 400-dataset for the following activities

Exercise 1 : test the difference between gender on salary independent t-test

Exercise 2 : The average motivation index = 3, please test the motivation against the average motivation

(Please present your answers on ppt with SPSS output incorporated)

ANOVA



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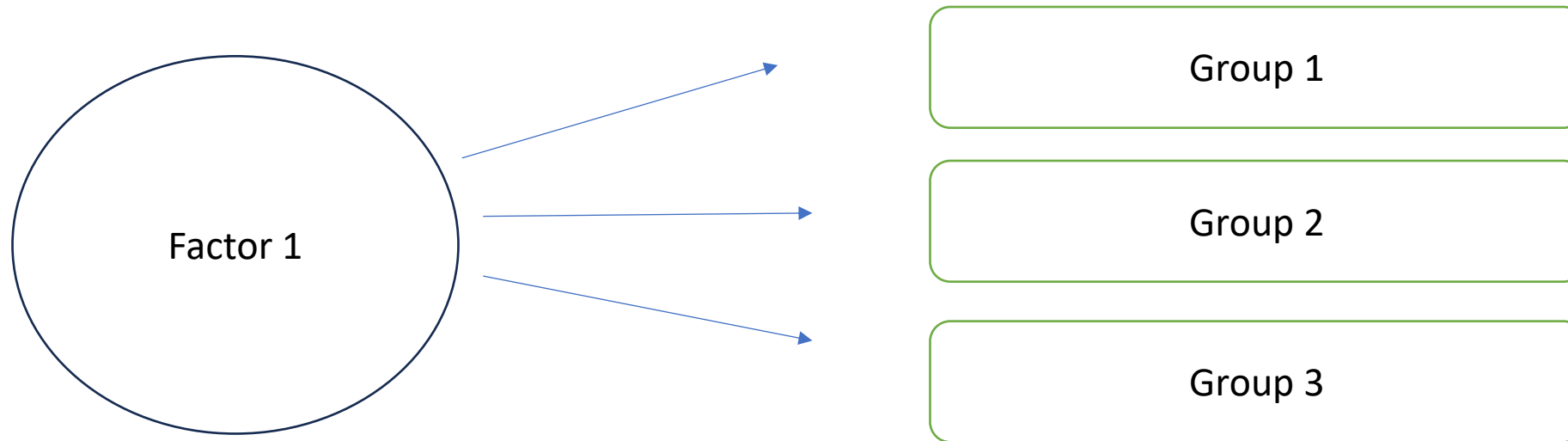
One-way ANOVA



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One-way ANOVA

One-way ANOVA: Used to determine how one factor affects a response variable.



If you need to compare differences between several groups on the same variables

→ One way ANOVA (For the maths, please see here:
http://web.pdx.edu/~newsomj/uvclass/ho_ANOVA.pdf)

It compares differences of means among more than 2 groups. It does this by looking at variation in the data and where that variation is found (hence its name). Specifically, **ANOVA** compares the amount of variation between groups with the amount of variation within groups.

BUT: It does not tell us which groups are different, only that there are differences between the variations for the variables for the groups.

Therefore, post hoc tests need to be run to determine which groups are different.



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One-way ANOVA – Assumption

- 1. Independence of observations:** the data were collected using statistically valid [sampling methods](#), and there are no hidden relationships among observations. If your data fail to meet this assumption because you have a [confounding variable](#) that you need to control for statistically, use an ANOVA with blocking variables.
- 2. Normally-distributed response variable:** The values of the dependent variable follow a [normal distribution](#).
- 3. Homogeneity of variance:** The variation within each group being compared is similar for every group. If the variances are different among the groups, then ANOVA probably isn't the right fit for the data.

One-way ANOVA

- **ANOVA**, which stands for Analysis of Variance, is a statistical test used to analyze the difference between the means of more than two groups.
- A **one-way ANOVA** uses one independent variable
- Use a one-way ANOVA when you have collected data about one categorical independent variable and one quantitative dependent variable. The independent variable should have at least three levels (i.e. at least three different groups or categories).

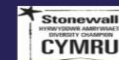
One-way ANOVA

ANOVA tells you if the dependent variable changes according to the level of the independent variable.

For example:

Independent variable is brand of soda, and you collect data on Coke, Pepsi, Sprite, and Fanta to find out if there is a difference in the price per 100ml.

Dependent variable is job satisfaction,



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Post hoc tests:

If your data meets the homogeneity of variances assumption, use Tukey's post hoc test.

If your data did not meet the homogeneity of variances assumption, you should consider running the Games Howell post hoc test.

If you don't know, run both and check, then use the appropriate test.

ANOVA results

- The **F** ratio is the ratio of two mean square **values**. If the null hypothesis is true, the **F** should be close to 1. A large **F** ratio means that the variation among group means is more than would be expected by chance
- [How to report ANOVA results](#)

One-way ANOVA

The screenshot shows the SPSS software interface. The 'Analyze' menu is open, and the 'Compare Means and Proportions' sub-menu is expanded, highlighting 'One-Way ANOVA...'. The data view shows a table with columns 'ID', 'Gender', and 'Age'. The 'Gender' column has values 1 and 2, and the 'Age' column has values ranging from 18.00 to 63.00.

ID	Gender	Age
26	1	28.00
27	1	28.00
28	1	42.00
29	1	42.00
30	1	42.00
31	1	23.00
32	1	23.00
33	1	23.00
34	1	19.00
35	1	19.00
36	1	19.00
37	1	18.00
38	1	18.00
39	1	18.00
40	2	23.00
41	2	45.00
42	2	63.00
43	2	55.00
44	2	26.00
45	2	30.00
46	2	42.00
47	2	27.00
48	2	37.00
49	2	42.00
50	2	27.00
51	2	37.00
52	2	27.00
53	2	37.00
54	2	42.00

One-way ANOVA

One-Way ANOVA

Dependent List:

Job Satisfaction [Jobsat]

Factor:

Role [Role]

☒ Estimate effect size for overall tests

OK Paste Reset Cancel Help

One-Way ANOVA: Options

Statistics

☐ Descriptive

☐ Fixed and random effects

☒ Homogeneity of variance test

☐ Brown-Forsythe test

☐ Welch test

☐ Means plot

Missing Values

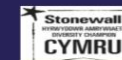
☒ Exclude cases analysis by analysis

☐ Exclude cases listwise

Confidence Intervals

Level(%): 0.95

Continue Cancel Help



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One-Way ANOVA: Post Hoc Multiple Comparisons

Equal Variances Assumed

☐ LSD ☐ S-N-K ☐ Waller-Duncan
☐ Bonferroni ☒ Tukey Type I/Type II Error Ratio: 100
☐ Sidak ☐ Tukey's-b ☐ Dunnett
☐ Scheffe ☐ Duncan Control Category: Last
☐ R-E-G-W F ☐ Hochberg's GT2
☐ R-E-G-W Q ☐ Gabriel

Test
☒ 2-sided ☐ < Control ☐ > Control

Equal Variances Not Assumed

☐ Tamhane's T2 ☐ Dunnett's T3 ☒ Games-Howell ☐ Dunnett's C

Null Hypothesis test

☒ Use the same significance level [alpha] as the setting in Options
☐ Specify the significance level [alpha] for the post hoc test
Level: 0.05

Continue Cancel Help

One-Way ANOVA: Options

Statistics

☒ Descriptive
☐ Fixed and random effects
☒ Homogeneity of variance test
☐ Brown-Forsythe test
☐ Welch test

☒ Means plot

Missing Values

☒ Exclude cases analysis by analysis
☐ Exclude cases listwise

Confidence Intervals

Level(%): 0.95



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One-way ANOVA

Descriptives

Job Satisfaction

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Temporary	10	1.6000	.51640	.16330	1.2306	1.9694	1.00	2.00
Operator	36	3.0556	.79082	.13180	2.7880	3.3231	2.00	4.00
Secretary	2	1.5000	.70711	.50000	-4.8531	7.8531	1.00	2.00
Team leader	8	3.3750	.51755	.18298	2.9423	3.8077	3.00	4.00
Management	2	5.0000	.00000	.00000	5.0000	5.0000	5.00	5.00
Total	58	2.8621	1.01650	.13347	2.5948	3.1293	1.00	5.00

Tests of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Job Satisfaction	Based on Mean	1.588	4	53	.191
	Based on Median	1.190	4	53	.326
	Based on Median and with adjusted df	1.190	4	50.910	.327
	Based on trimmed mean	1.629	4	53	.180

Levene Test is non-significant. The variance is equal
Group variances are homogeneous

One-way ANOVA

ANOVA

Job Satisfaction

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32.233	4	8.058	16.017	<.001
Within Groups	26.664	53	.503		
Total	58.897	57			

$$F(4, 53) = 16.017, p < .05, \eta^2 p = .547$$

$\eta^2 p$ is an effect size

One-way ANOVA

ANOVA Effect Sizes^a

		95% Confidence Interval		
		Point Estimate	Lower	Upper
Job Satisfaction	Eta-squared	.547	.322	.647
	Epsilon-squared	.513	.271	.620
	Omega-squared Fixed-effect	.509	.268	.616
	Omega-squared Random-effect	.206	.084	.286

a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.



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One-way ANOVA

Multiple Comparisons

Dependent Variable: Job Satisfaction

	(I) Role	(J) Role	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Temporary	Operator	-1.45556 [*]	.25354	<.001	-2.1715	-.7396
		Secretary	.10000	.54941	1.000	-1.4515	1.6515
		Team leader	-1.77500 [*]	.33645	<.001	-2.7251	-.8249
		Management	-3.40000 [*]	.54941	<.001	-4.9515	-1.8485
	Operator	Temporary	1.45556 [*]	.25354	<.001	.7396	2.1715
		Secretary	1.55556 [*]	.51529	.031	.1004	3.0107
		Team leader	-.31944	.27724	.778	-1.1023	.4634
		Management	-1.94444 [*]	.51529	.004	-3.3996	-.4893
	Secretary	Temporary	-.10000	.54941	1.000	-1.6515	1.4515
		Operator	-1.55556 [*]	.51529	.031	-3.0107	-.1004
		Team leader	-1.87500 [*]	.56074	.013	-3.4585	-.2915
		Management	-3.50000 [*]	.70929	<.001	-5.5030	-1.4970
	Team leader	Temporary	1.77500 [*]	.33645	<.001	.8249	2.7251
		Operator	.31944	.27724	.778	-.4634	1.1023
		Secretary	1.87500 [*]	.56074	.013	.2915	3.4585
		Management	-1.62500 [*]	.56074	.042	-3.2085	-.0415
	Management	Temporary	3.40000 [*]	.54941	<.001	1.8485	4.9515
		Operator	1.94444 [*]	.51529	.004	.4893	3.3996
		Secretary	3.50000 [*]	.70929	<.001	1.4970	5.5030
		Team leader	1.62500 [*]	.56074	.042	.0415	3.2085



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One-way ANOVA

Post-hoc testing

ANOVA will tell you if there are differences among the levels of the independent variable, but not which differences are significant. To find how the treatment levels differ from one another, perform a TukeyHSD (Tukey's Honestly-Significant Difference) post-hoc test.



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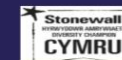
One-way ANOVA

Job Satisfaction					
Tukey HSD ^{a,b}	Role	N	Subset for alpha = 0.05		
			1	2	3
	Secretary	2	1.5000		
	Temporary	10	1.6000		
	Operator	36		3.0556	
	Team leader	8		3.3750	
	Management	2			5.0000
Sig.		1.000	.968	1.000	

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.991.

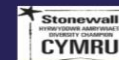
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.



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One-way ANOVA

There was a significant difference among the four regions on wickedness complaints, $F(3, 16) = 10.49, p < .001, \eta^2_p = .66$. Post hoc testing revealed significant differences between pairs of regions with North ($M = 1.00, SD = 1.23$) and South ($M = 1.40, SD = 1.14$) having fewer complaints than East ($M = 3.60, SD = 1.14$) and West ($M = 4.20, SD = 0.84$). These findings indicate that there are more wicked witch complaints in the East and West regions of Oz.



One-way ANOVA vs Two-way ANOVA

An **ANOVA**, short for “Analysis of Variance”, is used to determine whether or not there is a statistically significant difference between the means of three or more independent groups.

The two most common types of ANOVAs are the one-way ANOVA and the two-way ANOVA.

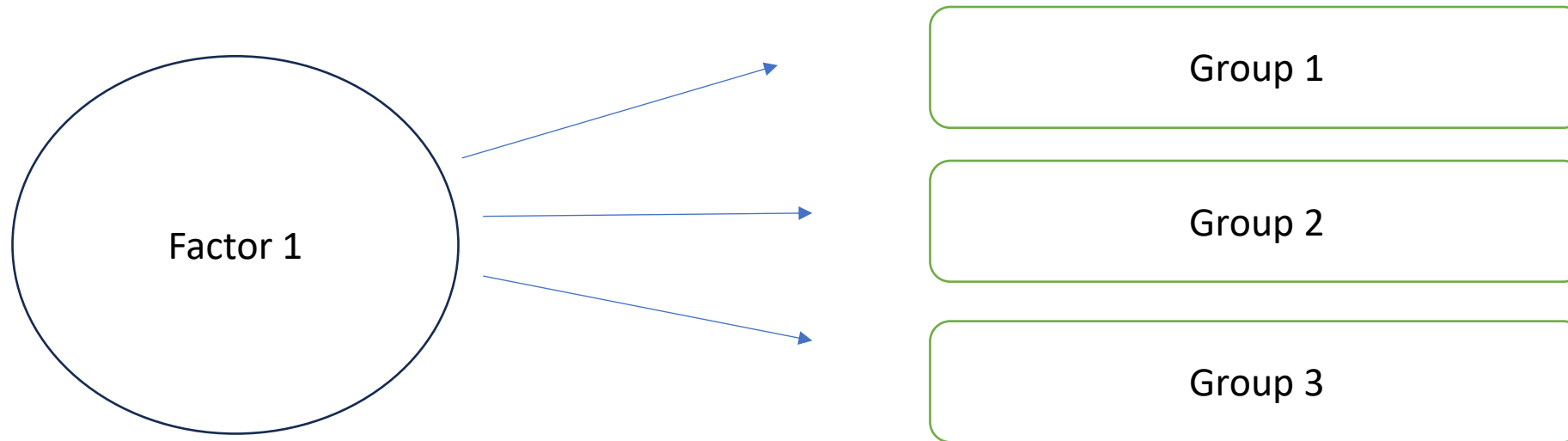
Two-way ANOVA



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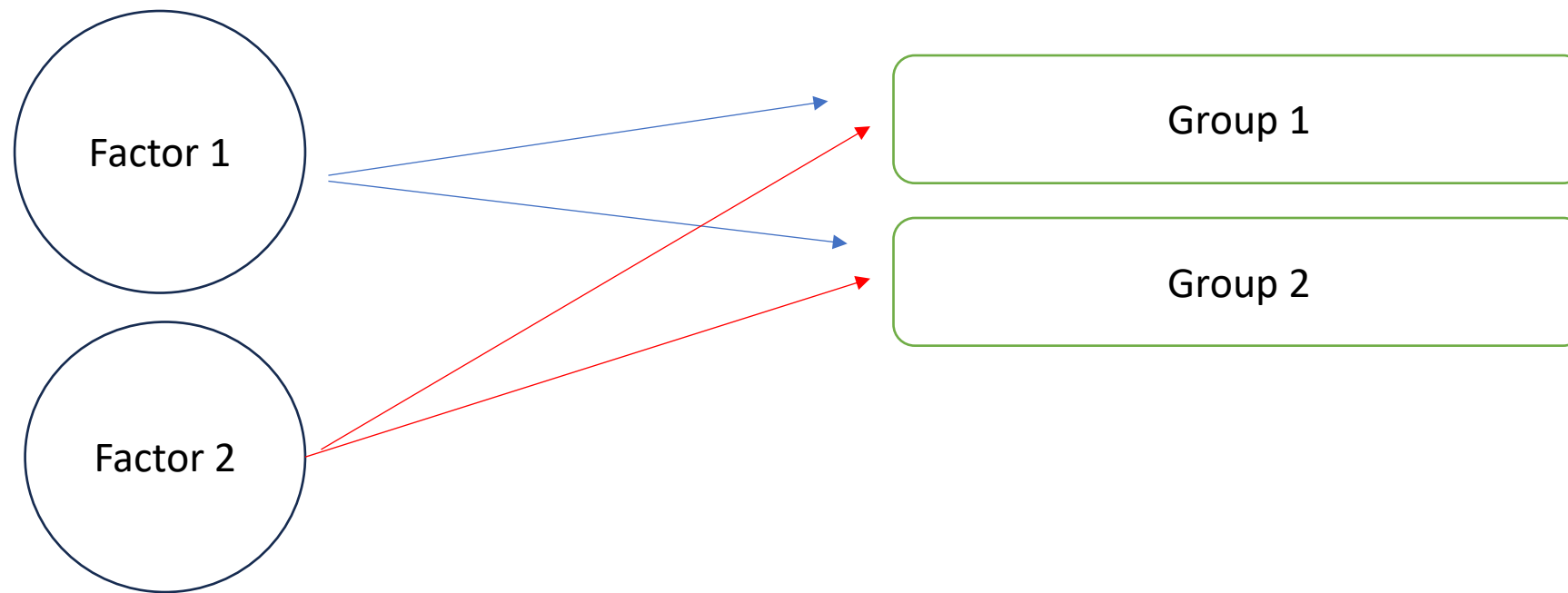
One-way ANOVA vs Two-way ANOVA

One-way ANOVA: Used to determine how one factor affects a response variable.



One-way ANOVA vs Two-way ANOVA

Two-way ANOVA: Used to determine how two factor affects a response variable.



Two-way ANOVA - Assumptions

- Your dependent variable should be continuous – that is, measured on a scale which can be subdivided using increments (i.e. grams, milligrams)

Your two independent variables – here, “month” and “sex”, should be in categorical, independent groups.

Sample independence – that each sample has been drawn independently of the other samples

Variance Equality – That the variance of data in the different groups should be the same

Normality – That each sample is taken from a normally distributed population

Two-way ANOVA – Hypothesis

H0: The means of all month groups are equal

H1: The mean of at least one month group is different

H0: The means of the sex groups are equal

H1: The means of the sex groups are different

H0: There is no interaction between the month and gender

H1: There is interaction between the month and gender

One-way vs Two-way ANOVA

	One-Way ANOVA	Two-Way ANOVA
Definition	A test that allows one to make comparisons between the means of three or more groups of data.	A test that allows one to make comparisons between the means of three or more groups of data, where two independent variables are considered.
Number of Independent Variables	One.	Two.
What is Being Compared?	The means of three or more groups of an independent variable on a dependent variable.	The effect of multiple groups of two independent variables on a dependent variable and on each other.
Number of Groups of Samples	Three or more	Each variable should have multiple samples.

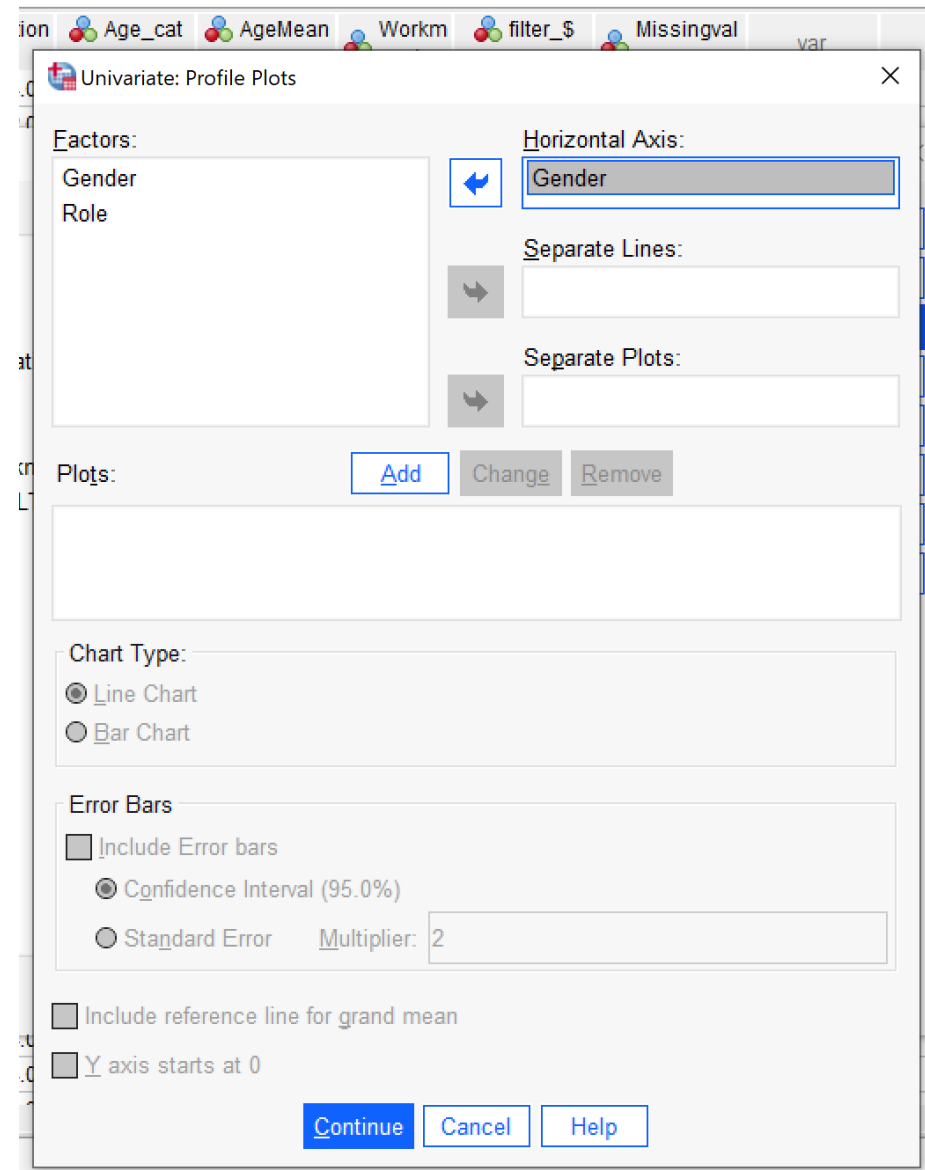
Source : Techology Network Informatics

Two-way ANOVA

SPSS menu path: **Analyze > General Linear Model > Univariate...**

	Age_cat	AgeMean	Workmode	filter_\$	Missingvalue	var
00	4.00	5.00	1.00	1	.00	
00	2.00	2.00	1.00	1	.00	
00	3.00	4.00	1.00	1	.00	
00	3.00	3.00	2.00	1	.00	
00			2.00	1	.00	
00			2.00	1	.00	
00			2.00	1	.00	
00			2.00	1	.00	
00	2.00	2.00	2.00	1	.00	
00	5.00	5.00	2.00	1	.00	
00	4.00	3.00	2.00	1	.00	
00	4.00	4.00	2.00	1	.00	
00	3.00	3.00	1.00	1	.00	
00	3.00	3.00	1.00	1	.00	
00	2.00	2.00	1.00	1	.00	
00	3.00	4.00	1.00	1	.00	
00	3.00	4.00	1.00	1	.00	
00	5.00	2.00	1.00	1	.00	

Click 'Gender' and add



The image shows the 'Univariate: Profile Plots' dialog box in SPSS. The 'Factors' list on the left contains 'Gender' and 'Role'. The 'Horizontal Axis' field on the right contains 'Gender'. The 'Separate Lines' and 'Separate Plots' fields are empty. The 'Plots' section has an 'Add' button. The 'Chart Type' section has 'Line Chart' selected. The 'Error Bars' section has 'Include Error bars' checked, with 'Confidence Interval (95.0%)' selected and a 'Multiplier' of 2. The 'Include reference line for grand mean' and 'Y axis starts at 0' options are unchecked. The 'Continue', 'Cancel', and 'Help' buttons are at the bottom.

ion Age_cat AgeMean Workm filter_\$ Missingval var

Univariate: Profile Plots

Factors:

Gender
Role

Horizontal Axis:

Gender

Separate Lines:

Separate Plots:

Plots: Add Change Remove

Chart Type:

☒ Line Chart
☐ Bar Chart

Error Bars

☒ Include Error bars

☒ Confidence Interval (95.0%)
☐ Standard Error Multiplier: 2

☐ Include reference line for grand mean
☐ Y axis starts at 0

Continue Cancel Help

Click 'ROLE' and add

Univariate: Profile Plots

Factors:
Gender
Role

Horizontal Axis:
Role

Separate Lines:
[]

Separate Plots:
[]

Plots:
Gender

Chart Type:
☒ Line Chart
☐ Bar Chart

Error Bars
☐ Include Error bars
☒ Confidence Interval (95.0%)
☐ Standard Error Multiplier: 2

☐ Include reference line for grand mean
☐ Y axis starts at 0

Continue Cancel Help

Click 'ROLE and Gender' and add

Univariate: Profile Plots

Factors:

Gender
Role

Horizontal Axis:

Role

Separate Lines:

Gender

Separate Plots:

Plots:

Add Change Remove

Gender
Role

Chart Type:

☒ Line Chart
☐ Bar Chart

Error Bars

☐ Include Error bars

☒ Confidence Interval (95.0%)
☐ Standard Error Multiplier: 2

☐ Include reference line for grand mean

☐ Y axis starts at 0

Continue Cancel Help

Click 'ROLE and Gender' and add

Univariate: Profile Plots

Factors:

Gender
Role

Horizontal Axis:

Separate Lines:

Separate Plots:

Plots:

Gender
Role
Role*Gender

Chart Type:

☒ Line Chart
☐ Bar Chart

Error Bars

☐ Include Error bars

☒ Confidence Interval (95.0%)
☐ Standard Error Multiplier: 2

☐ Include reference line for grand mean

☐ Y axis starts at 0

Continue Cancel Help

Click 'ROLE and Gender' and add

Univariate: Profile Plots

Factors:

Gender
Role

Horizontal Axis:

Separate Lines:

Separate Plots:

Plots:

Add Change Remove

Gender
Role
Role*Gender

Chart Type:

☒ Line Chart
☐ Bar Chart

Error Bars

☐ Include Error bars

☒ Confidence Interval (95.0%)
☐ Standard Error Multiplier: 2

☐ Include reference line for grand mean

☐ Y axis starts at 0

Continue Cancel Help

Two-way ANOVA

Univariate

Dependent Variable:
Job Satisfaction [Jobsat]

Fixed Factor(s):
Gender [Gender]
Role [Role]

Random Factor(s):

Covariate(s):

WLS Weight:

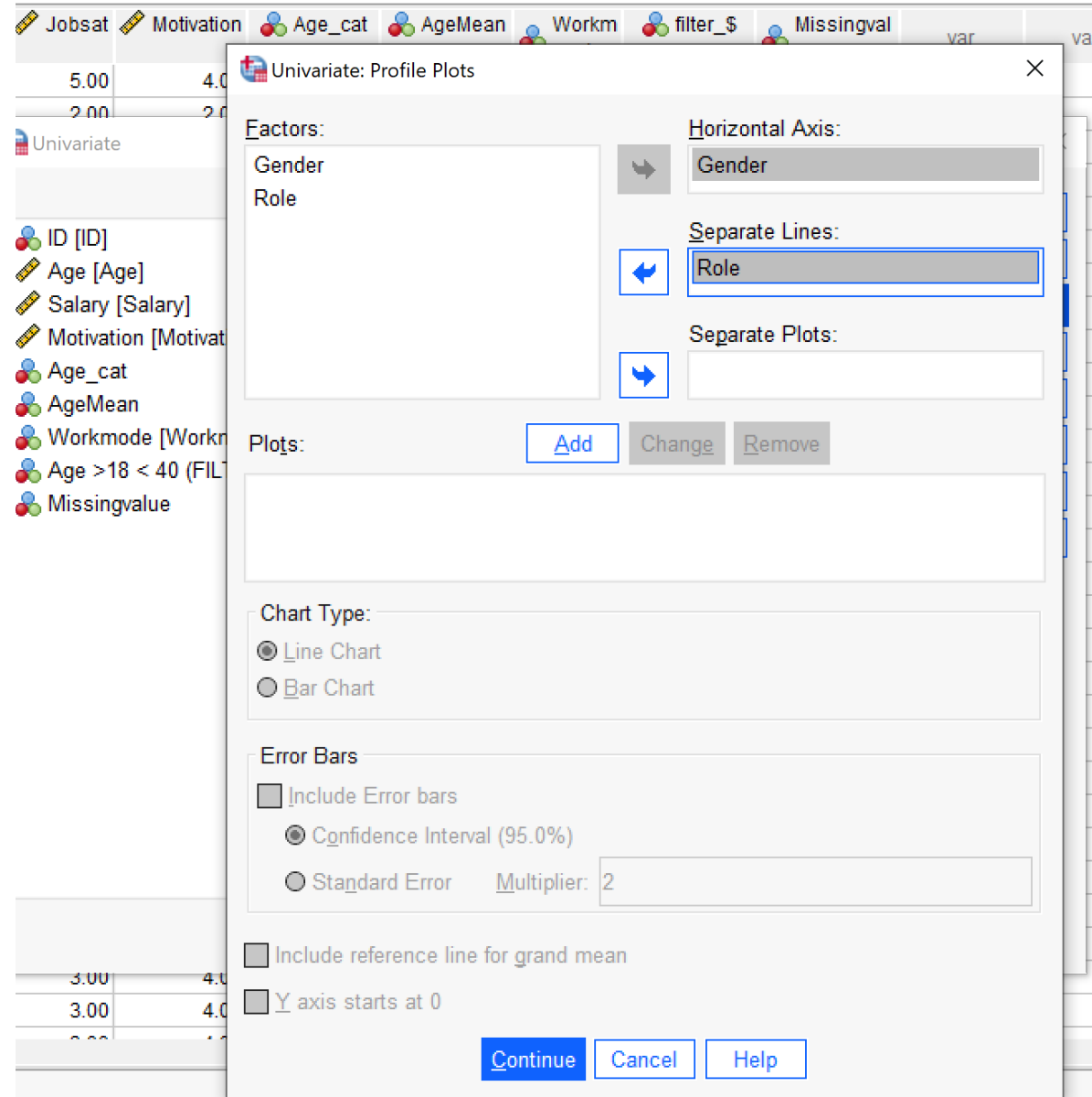
OK Paste Reset Cancel Help

Model...
Contrasts...
Plots...
Post Hoc...
EM Means...
Save...
Options...
Bootstrap...

ID [ID]
Age [Age]
Salary [Salary]
Motivation [Motivation]
Age_cat
AgeMean
Workmode [Workmode]
Age >18 < 40 (FILTER) [filter_\$]
Missingvalue

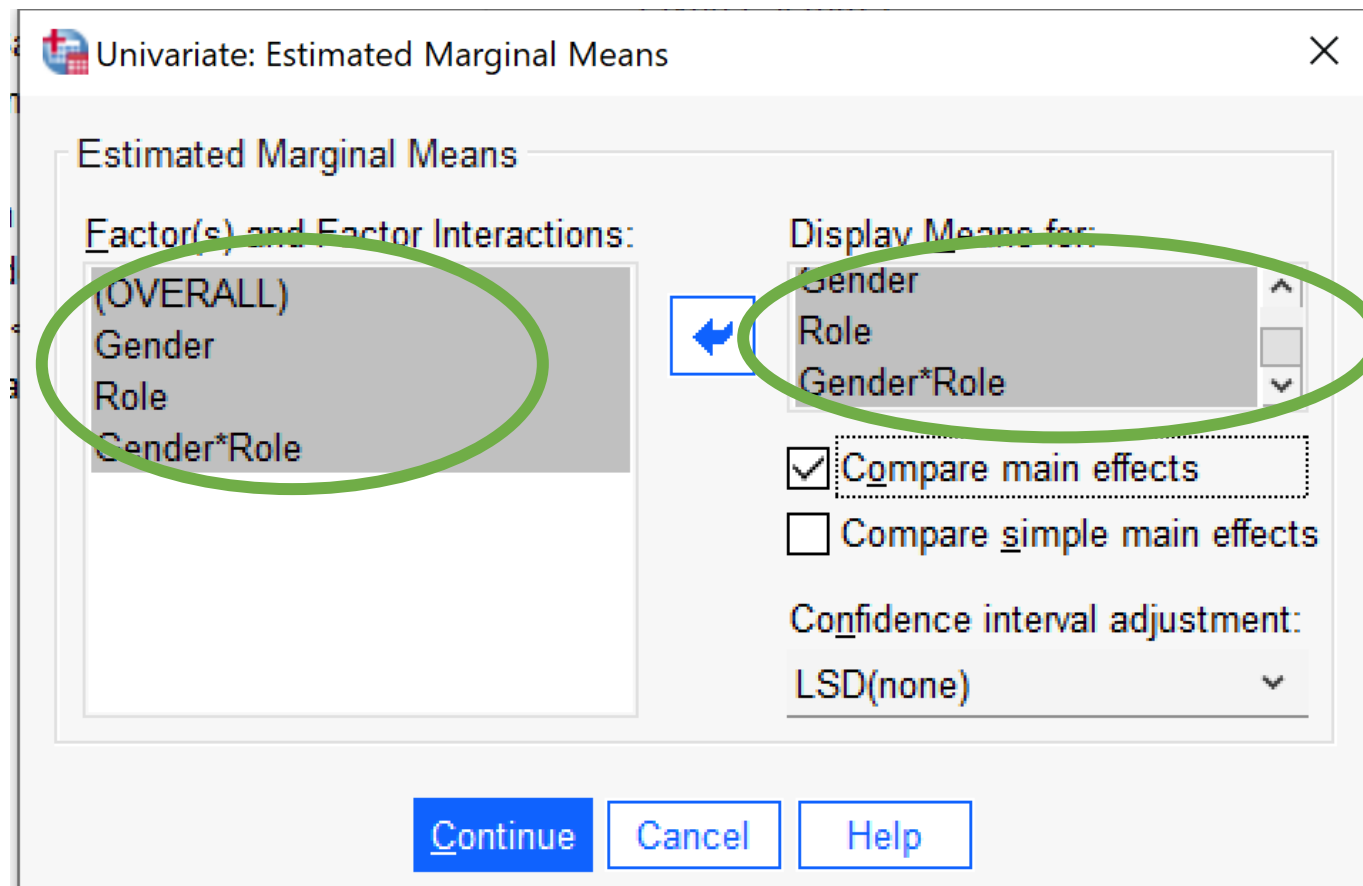
Two-way ANOVA

Go to 'plot'



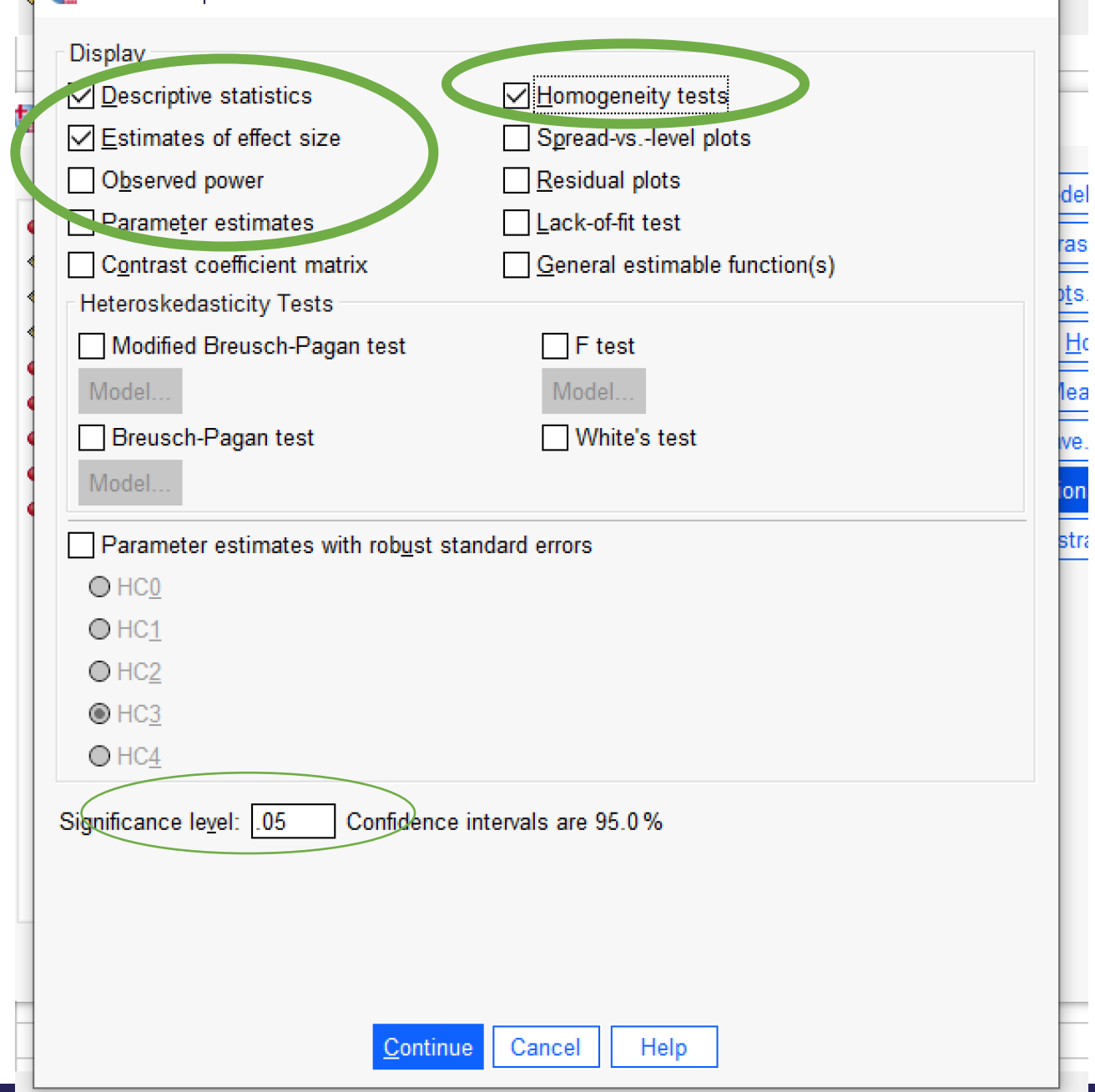
Two-way ANOVA

Go to Post Hoc
and add 'Role'



Two-way ANOVA

Go to Option
and add 'Role'



The image shows the 'Two-way ANOVA: Display' and 'Heteroskedasticity Tests' dialog box in SPSS. The 'Display' section has two columns of options. The first column includes 'Descriptive statistics', 'Estimates of effect size', 'Observed power', 'Parameter estimates', and 'Contrast coefficient matrix'. The second column includes 'Homogeneity tests', 'Spread-vs.-level plots', 'Residual plots', 'Lack-of-fit test', and 'General estimable function(s)'. The 'Homogeneity tests' option is checked. The 'Heteroskedasticity Tests' section includes 'Modified Breusch-Pagan test', 'Breusch-Pagan test', 'F test', and 'White's test'. The 'Parameter estimates with robust standard errors' section includes radio buttons for HC0, HC1, HC2, HC3, and HC4. The 'Significance level' is set to .05 and 'Confidence intervals are 95.0 %'. The 'Continue', 'Cancel', and 'Help' buttons are at the bottom.

Display

- ☒ Descriptive statistics
- ☒ Estimates of effect size
- ☐ Observed power
- ☐ Parameter estimates
- ☐ Contrast coefficient matrix
- ☒ Homogeneity tests
- ☐ Spread-vs.-level plots
- ☐ Residual plots
- ☐ Lack-of-fit test
- ☐ General estimable function(s)

Heteroskedasticity Tests

- ☐ Modified Breusch-Pagan test
- ☐ Breusch-Pagan test
- ☐ F test
- ☐ White's test

Parameter estimates with robust standard errors

- ☐ HC0
- ☐ HC1
- ☐ HC2
- ☒ HC3
- ☐ HC4

Significance level: .05 Confidence intervals are 95.0 %

Continue Cancel Help

Two-way ANOVA

SPSS Output

Between-Subjects Factors

		Value Label	N
Gender	1	Male	39
	2	Female	19
Role	1	Temporary	10
	2	Operator	36
	3	Secretary	2
	4	Team leader	8
	5	Management	2

Two-way ANOVA

Levene's Test of Equality of Error Variances^{a,b}

SPSS
Output

		Levene Statistic	df1	df2	Sig.
Job Satisfaction	Based on Mean	5.619	6	50	<.001
	Based on Median	1.604	6	50	.166
	Based on Median and with adjusted df	1.604	6	33.973	.176
	Based on trimmed mean	5.679	6	50	<.001

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

- a. Dependent variable: Job Satisfaction
- b. Design: Intercept + Gender + Role + Gender * Role

Two-way ANOVA

$P < 0.05$
Significantly different

Tests of Between-Subjects Effects

Dependent Variable: Job Satisfaction

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	37.291 ^a	7	5.327	12.329	<.001	.633
Intercept	158.927	1	158.927	367.794	<.001	.880
Gender	2.903	1	2.903	6.719	.012	.118
Role	24.163	4	6.041	13.980	<.001	.528
Gender * Role	.237	2	.118	.274	.762	.011
Error	21.605	50	.432			
Total	534.000	58				
Corrected Total	58.897	57				

a. R Squared = .633 (Adjusted R Squared = .582)

SPSS
Output

Two-way ANOVA

Compare
between groups
by pair

Pairwise Comparisons

Dependent Variable: Job Satisfaction

(I) Role	(J) Role	Mean Difference (I-J)	Std. Error	Sig. ^d	95% Confidence Interval for Difference ^d	
					Lower Bound	Upper Bound
Temporary	Operator	-1.605 [*]	.366	<.001	-2.341	-.869
	Secretary	-.167 ^b	.580	.775	-1.331	.998
	Team leader	-2.167 [*]	.421	<.001	-3.013	-1.320
	Management	-3.667 ^{*,b}	.580	<.001	-4.831	-2.502
Operator	Temporary	1.605 [*]	.366	<.001	.869	2.341
	Secretary	1.438 ^{*,b}	.480	.004	.474	2.402
	Team leader	-.562 [*]	.268	.041	-1.100	-.024
	Management	-2.062 ^{*,b}	.480	<.001	-3.026	-1.098
Secretary	Temporary	.167 ^c	.580	.775	-.998	1.331
	Operator	-1.438 ^{*,c}	.480	.004	-2.402	-.474
	Team leader	-2.000 ^{*,c}	.523	<.001	-3.051	-.949
	Management	-3.500 ^{*,b,c}	.657	<.001	-4.820	-2.180
Team leader	Temporary	2.167 [*]	.421	<.001	1.320	3.013
	Operator	.562 [*]	.268	.041	.024	1.100
	Secretary	2.000 ^{*,b}	.523	<.001	.949	3.051
	Management	-1.500 ^{*,b}	.523	.006	-2.551	-.449
Management	Temporary	3.667 ^{*,c}	.580	<.001	2.502	4.831
	Operator	2.062 ^{*,c}	.480	<.001	1.098	3.026
	Secretary	3.500 ^{*,b,c}	.657	<.001	2.180	4.820
	Team leader	1.500 ^{*,c}	.523	.006	.449	2.551

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

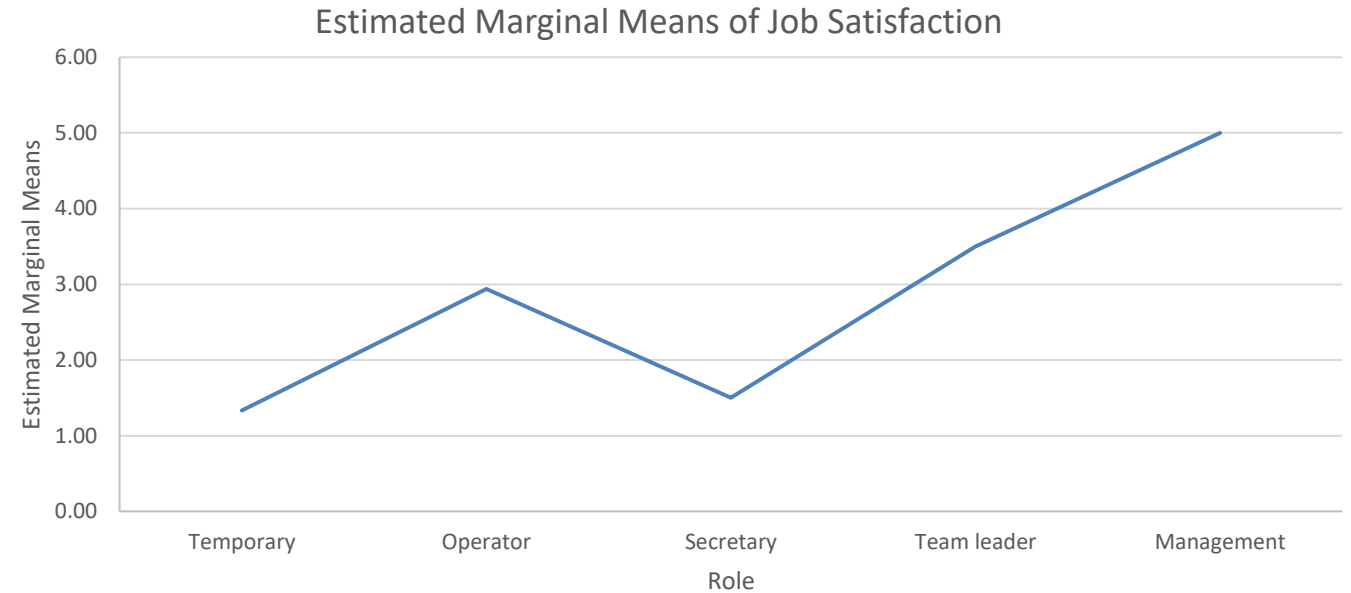
b. An estimate of the modified population marginal mean (J).

c. An estimate of the modified population marginal mean (I).

d. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Two-way ANOVA

SPSS Output



Two-way ANOVA

SPSS Output

Descriptive Statistics

Dependent Variable: Job Satisfaction

Gender	Role	Mean	Std. Deviation	N
Male	Temporary	1.6667	.50000	9
	Operator	3.2400	.72342	25
	Team leader	4.0000	.00000	3
	Management	5.0000	.00000	2
	Total	3.0256	1.06344	39
Female	Temporary	1.0000	.	1
	Operator	2.6364	.80904	11
	Secretary	1.5000	.70711	2
	Team leader	3.0000	.00000	5
	Total	2.5263	.84119	19
Total	Temporary	1.6000	.51640	10
	Operator	3.0556	.79082	36
	Secretary	1.5000	.70711	2
	Team leader	3.3750	.51755	8
	Management	5.0000	.00000	2
	Total	2.8621	1.01650	58

In-class activity

Please use the 400-dataset for the following activities

Exercise 1. Please test satisfaction level according to role through One-way ANOVA

Exercise 2. Please test the satisfaction level between gender and role through Two-way ANOVA

(Please present your answers on ppt with SPSS output incorporated)



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Q&A



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