MEANS COMPARISON

In the previous chapter we already got an idea about hypothesis testing. In this chapter you will see how to apply what we have learned to perform some statistical analyses. The focus on this chapter is on means comparison. *Means comparison* is a statistical analysis that the researchers undertake to compare whether the means between two or more sample groups tend to differ from one another or not.

One research topic that involves mean comparison that we will use as an example later is a study about income equality between males and females. Given the significant change in socioeconomic status of females in the modern world, the roles of females in a workforce tend to become more prominent than in the past. Nowadays, it is unarguable that many females have begun to be at a higher position in an organization and earn higher income than males. In this regards, the researchers may be interested in investigating whether the average income of males and females tend to differ or not. The comparison of mean salaries between males and females will provide empirical evidence to this research question.

Another example that we will use for means comparison is about the role of educational degree and salary that people can earn. Given that nowadays people tend to put more emphasis on getting higher education such as master's degree and doctoral degree, the researchers may be interested in testing whether people who get higher education actually earn more income than people who have lower education or not. In this case, comparing mean salary among people in different educational levels is useful to provide empirical evidence to this research question as well.

In particular, this chapter focuses on two statistical techniques that are widely used to compare means: the first is independent samples t-test; the second is one way analysis of variance (ANOVA). The major difference between these two techniques is the numbers of sample group that are used to compare. Basically, independent samples t-test is a technique that allows a comparison of means between two groups, whereas ANOVA allows a comparison of means among three or more groups.

INDEPENDENT SAMPLES T-TEST

As already mentioned at the beginning, *independent samples t-test* is a statistical technique that allows researchers to compare means between two unrelated groups. In order to perform the independent samples t-test, there are several basic assumptions that should be met. First, the variables to be compared must be continuous variable. Note that *continuous variable* is a variable that can take on any value in a certain range. Some examples include test score, income, temperature, etc. Second, the groups that will be compared must comprise of 2 groups (e.g., male and female, single person and married person, part-time employees and full-time employees). Especially in the process of data analysis, each group must be coded as categorical variable. Note that a *categorical variable* is a variable that can take on fixed number of possible values; its main purpose is to assign each individual to a particular group or category (e.g. male is coded 0; female is coded 1).

Refer to what we have already learned about hypothesis test, null hypothesis and alternative hypothesis for independent samples t-test are stated as the following:

$$H_0: \text{Mean}_{\text{Group 1}} = \text{Mean}_{\text{Group 2}}$$
$$H_a: \text{Mean}_{\text{Group 1}} \neq \text{Mean}_{\text{Group 2}}$$

Again, the decision whether null hypothesis can be rejected needs to be justified by a p-value. If the p-value fail to reject the null hypothesis (which means that the p-value is greater than .05), we conclude that means between two groups are equal. But if the p-value reject the null hypothesis (which means that the p-value is lower than or equal to .05), we conclude that means between two groups significantly differs.

By the way, another key assumption of independent samples t-test that needs to be met is that the data of two groups to be compared must inherit homogeneity of variances. Simply put, this requirement suggests that variances in the data between the groups that we aim to compare must be equal. This assumption can be tested by *Levene's test for equality of variances*. But why variances of data between to

group should be equal? In statistics sense, variance is the square terms of standard deviation which represents how far each value in the data set is from the mean. It signifies the quality of the data. Of course the data that has low variance is better than the data that has high variance. Anyway, let's use boxing as the analogy to help you understand why variances between groups have to be equal so that means can be compared with less bias. Before professional boxers fight in the boxing match to see who is better, it is important to make sure that both of them fit in the same weight class to make it fair in the fight.   Of course, a light flyweight boxer has to fight with a light flyweight boxer; a heavyweight boxer has to fight with heavyweight boxer. From this analogy, comparing variances in the data between two groups before we compare their means also serve the same purpose.   If variance in the data of the first group is high (low), variance in the data of the second group should be high (low) as well.

The null hypothesis and the alternative hypothesis for Levene's test for equality of variances can be declared as the following:

$$H_0: \text{Variance}_{\text{Group 1}} = \text{Variance}_{\text{Group 2}}$$
$$H_a: \text{Variance}_{\text{Group 1}} \neq \text{Variance}_{\text{Group 2}}$$

If the p-value fails to reject the null hypothesis (which means that the p-value is greater than .05), we conclude that variances between two groups are equal. Conversely, if the p-value reject the null hypothesis (which means that the p-value is lower than or equal to .05), we conclude that variances between two groups significantly differs.   In particular, because the homogeneity of variances assumption requires that variances between two groups have to be equal, we expect a p-value from the Levene's test to be higher than .05 so that the null hypothesis of equal variance can be confirmed. However, note that even though the assumption of homogeneity of variances is not met, SPSS also provide alternative results that can be used to make a conclusion (you will see it later). So it is alright if the result from Levene's test for equality of variances shows that the null hypothesis of the test is rejected.

Performing independent samples t-test in SPSS
In this section we will learn how to perform independent samples t-test in SPSS. There are two research topics that will be used as the examples. The first is a study about salary difference between males and females. The second is a study about salary difference between part-time and full-time employees.

Research example 1: Salary difference between males and females
In the beginning of this chapter we already gave two examples of study that requires means comparison. The first is the comparison of income between males and females. Now, let's use the independent samples t-test in SPSS to provide evidence whether males and females actually earn different level of salary on average or not. In this case, the null hypothesis and the alternative hypothesis that we will prove are stated as the following:

$$H_0: \text{Salary }_{Males} = \text{Salary }_{Females}$$
$$H_a: \text{Salary }_{Males} \neq \text{Salary }_{Females}$$

Note that although the author mentioned in the beginning that nowadays many females tend to earn more than males, this is just only the assumption that the author made. In reality, we don't know which gender actually earn more income. So in the alternative hypothesis it is not predicted which gender group earn more salary than another; it is also regarded as a two-tailed hypothesis.
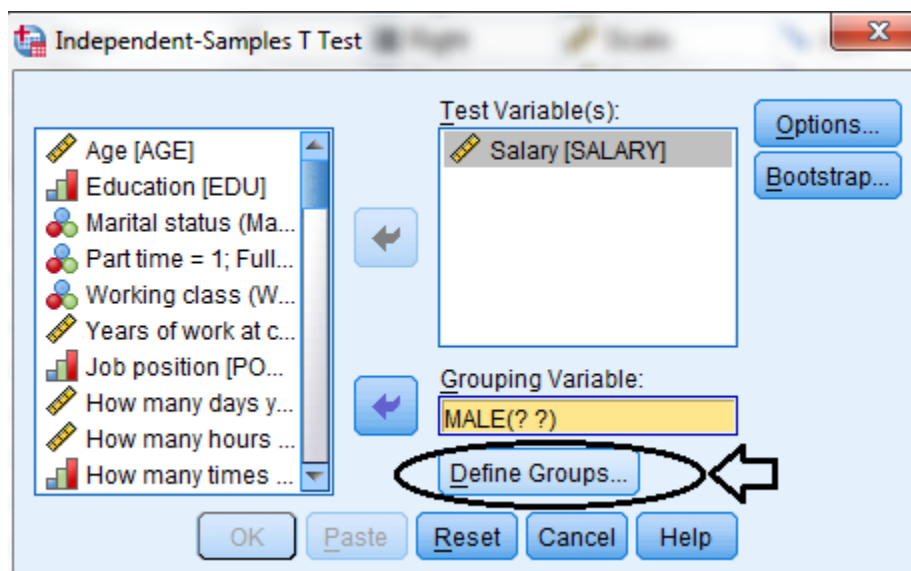
To begin, select **Analyze**
… Compare Means
… Independent –Samples T Test
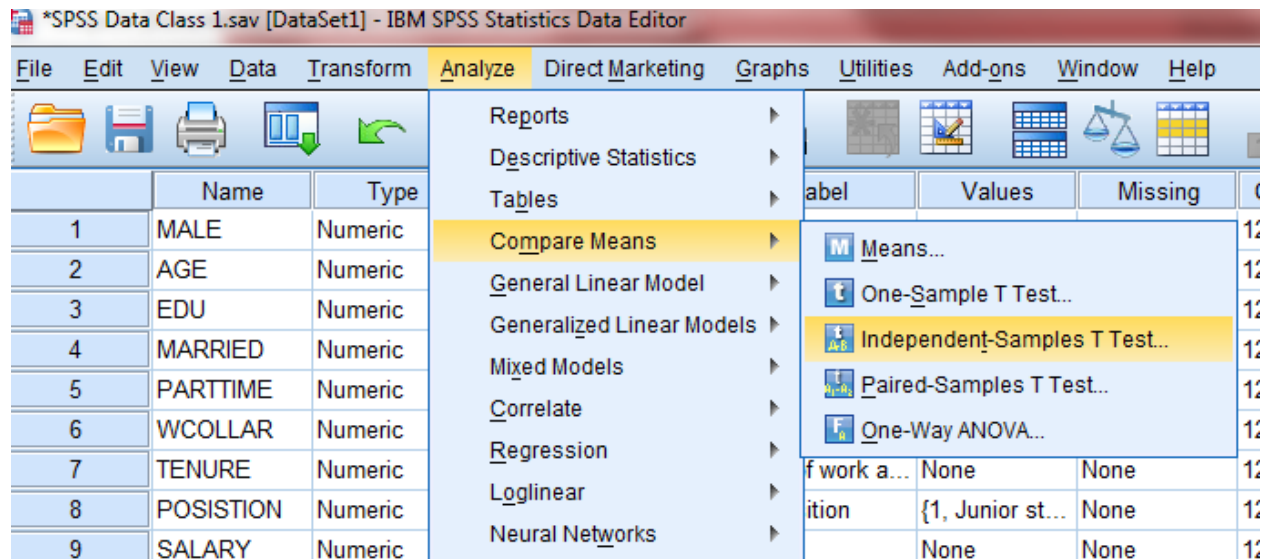
Because salary is the factor that will be compared, we drag the variables into the field **Test Variable(s).** Because we want to compare salary between males and females, we drag gender into the field **Grouping variable**.

Then click on the bottom "**Define groups…**"

Because gender was coded as a dummy variable whereby male takes the value 1 and female takes the value 0, we have to tell the software about the code that we set for each group.
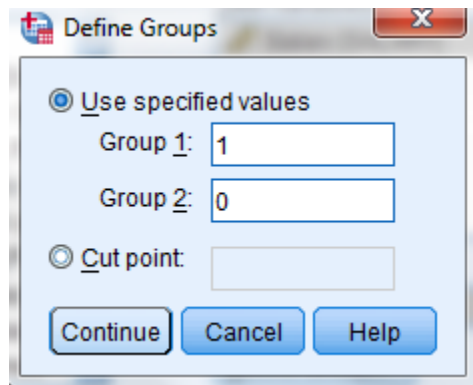
After that, click **Continue**, and then **Ok**. The software will show two tables as the following.

Group Statistics

	Gender (Male=1)	N	Mean	Std. Deviation	Std. Error Mean
Salary	male	46	44244.20	32612.405	4808.437
	female	40	34037.48	21738.902	3437.222

The first table reports means of two groups. The column "N" indicates that the sample comprises of 46 male and 40 female. The column "Mean" provides the mean salary of each group. Here it indicates that on average males earn salary about 44,244.20 THB, whereas females earn salary on average about 34,037.48 THB.

Although the information from this table implies that on average males earn more salary than females about 10,206.72 THB (that is, 44,244.20 THB - 34,037.48 THB), we cannot make a final conclusion from this table. Information in this table only gives you rough idea about mean difference. We have to determine the p-value to prove that the mean difference that we got does not happen by chance.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Salary	Equal variances assumed	2.640	.108	1.681	84	.097	10206.721	6073.355	-1870.812	22284.253
	Equal variances not assumed			1.727	78.952	.088	10206.721	5910.631	-1558.208	21971.649

As a rule of thumb, there are three steps that you need to follow when you interpret the results from independent samples t-test in SPSS

1. Check whether the equality of variances assumption is met or not based on a p-value of a Levene's Test for equality of Variances.
2. Based on the finding in step 1, decide on whether you should use the results from the row "Equal variances assumed" or "Equal variances not assumed" to interpret the t-test for equality of means.
3. Interpret means difference between two groups and make a conclusion based on a p-value of a t-test for equality of means.

If you notice in the first column of the table you can see that the first row is labeled "Equal variances assumed" whereas the second row are labeled "Equal variances not assumed". Technically, the first step of the independent samples t-test is to check whether the equality of variances assumption is met or not. The decision to use results from the first row or the second row will be determined by the results from "Levene's Test for equality of Variances" that are shown in the second column and the third column of the table. The second column reports the F-statistics that is calculated for the Levene's test, whereas the third column reports the *p-value* of the F-statistics.

		Levene's Test for Equality of Variances	
		F	Sig.
Salary	Equal variances assumed	2.640	.108
	Equal variances not assumed		

Again, the null hypothesis and the alternative hypothesis for Levene's Test for equality of Variances are declared as the following:

$$H_0: \text{Variance}_{\text{salary of male}} = \text{Variance}_{\text{salary of female}}$$
$$H_a: \text{Variance}_{\text{salary of male}} \neq \text{Variance}_{\text{salary of female}}$$

If the p-value is more than .05, we *fail to reject* the null hypothesis that variances between two groups are equal; and thus, we can use results from the first row (equal variances assumed) to make a decision. On the other hand, if the p-value is less than or equal to .5, then we *reject* the null hypothesis that variances between two groups are equal (which means that alternative hypothesis is true); and thus we must use results from the second row (equal variances not assumed) to make a decision.

The results from Levene's test shows that a p-value of the test is .108. Because the p-value is higher than the 0.05 threshold, we *fail to reject* the null hypothesis that variances between two groups are equal. In this case, the assumption about the equality of variances between two groups is statistically confirmed. Thus, we can use results in the first row (equal variances assumed) to make a decision.

Independent Samples Test

|		Levene's Test for Equality of Variances		t-test for Equalit			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Salary	Equal variances assumed	2.640	.108	1.681	84	.097	10206.721
	Equal variances not assumed			1.727	78.952	.088	10206.721

The sections in the table that present the results of means difference are under "t-test of equality of means". Before we use a p-value to make a decison, let's take quick look at the column "mean difference". It shows the difference in means of salary between males and females, which is equal to 10,206.721 THB (44,244.20 THB - 34,037.48 THB). Note that the value of mean difference is similar to the calculation that was shown in the upper table.

The column Sig (2-tailed) presents that p-value of the t-test for equality of means that we will use to make a decision whether we can reject a null hypothesis which states that two groups have equal means. Here you can see that a p-value is equals

to .097. Because a p-value of .097 is higher than .05, we fail to reject a null hypothesis which states that mean salary between males and females are equal. Lack of statistical significance suggests that mean difference between males and females just happens by chance. Therefore, the conclusion we can make based on this finding is that although on average males earns higher salary than females about 10,206.72 THB, this mean difference is not statistically significant. In statistic sense, the mean difference between male and female cannot be supported.

Research example 2: Salary difference between full-time and part-time employees
Now let's see another example of research that uses independent samples t-test to compare means. Suppose that we want to investigate whether full-time and part-time employees earn equal level of income or not. This may be quite easy to guess. To analysis this, we need to change the grouping variable by using the categorical variable named 'PARTIME', which is a dummy variable that measures whether an employee is a part-time employee (part-time was coded 1; full-time was coded 0).
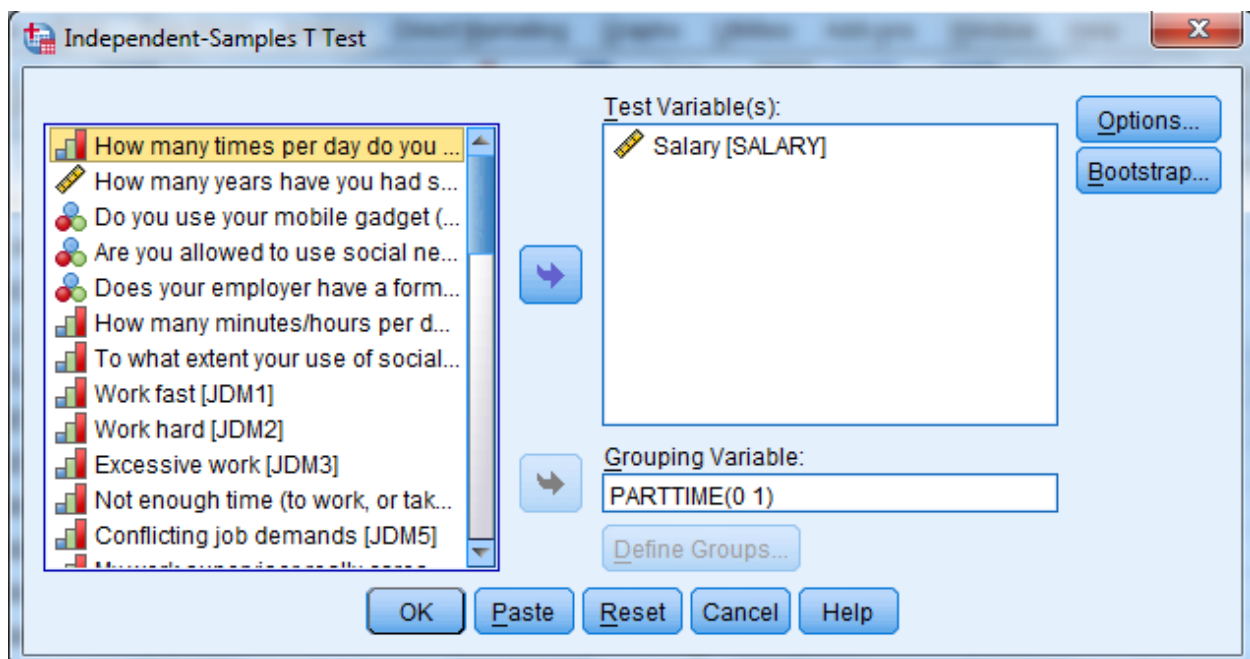
After you click OK button to run the analysis, the first table tells you that on average full-time employees earn about 47,941 TBH, whereas part-time employees

earn about 11,630 THB. From this information, it is obvious that full-time employees earn more than part-time employee by 47,941- 11,630 = 36,310 THB. However, we need to use the test-statistics and the p-value from independent samples t-test to confirm that the finding is statistically supported and do not happen by chance.

Group Statistics

	Part time = 1; Full time = 0	N	Mean	Std. Deviation	Std. Error Mean
Salary	full time job	66	47941.15	26806.595	3299.664
	part time job	20	11630.80	9104.648	2035.861

But before we make a conclusion whether two groups have equal mean or not, we have to check the equality of variances between them first. You can see that a p-value of the Levene's test is .002, which is a lot lower than .05. You may say that it is statistically significant at the 1 percent level). Thus, we can reject a null hypothesis which states that variances are equal.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality			
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Salary	Equal variances assumed	10.595	.002	5.933	84	.000	36310.352
	Equal variances not assumed			9.365	82.839	.000	36310.352

Because we know that the variances between two groups are unequal, we need to use the results in the second row to interpret a t-test for quality of means. In particular, the p-value of .000 which is greatly lower than .05 (it is statistically significant at the .1 percent level) tells us that we can reject null hypothesis which states that means between two groups are equal. This automatically confirms alternative hypothesis about the inequality of means. Thus, we can conclude that on average full-time employees tend to earn more salary than part-time employee by 36,310 THB, and this mean difference is statistically supported.

ONE WAY ANALYSIS OF VARIANCE (ANOVA)

Previously we used independent samples t-test to compare means. However, the main limitation of independent samples t-test is that it only allows you compare means between two groups at a time. If you have more than two groups to compare their means, you need another statistical technique called *one-way analysis of variance (ANOVA)*.

Similar to the independent samples t-test, null hypothesis and alternative hypothesis in ANOVA are stated as the following.

$$H_0: \text{Mean}_{\text{Group 1}} = \text{Mean}_{\text{Group 2}} = \text{Mean}_{\text{Group 3}}$$
$$H_a: \text{Mean}_{\text{Group 1}} \neq \text{Mean}_{\text{Group 2}} \neq \text{Mean}_{\text{Group 3}}$$

The only difference from what we did in independent samples t-test is that there are more than two groups involved in the analysis. The decision to reject null hypothesis is justified by p-value associated with its test statistics. For ANOVA, if a p-value fail to reject the null hypothesis (which means that the p-value is greater than .05), we conclude that means among all groups that we compare are equal. However, if a p-value rejects the null hypothesis (which means that the p-value is lower than or equal to .05), we conclude that *at least two groups has unequal means*.

Generally, ANOVA requires basic assumptions that independent samples t-test does. Similarly, we have to assess whether variances in the data of all groups that we are comparing are equal or not. In this case, the Levene's Test for equality of Variances is also required in ANOVA. The null hypothesis and the alternative hypothesis for Levene's Test for equality of Variances are declared similar to what we performed in the independent samples t-test, except for that there are more than two groups in the hypotheses.

$$H_0: \text{Variance}_{\text{Group 1}} = \text{Variance}_{\text{Group 2}} = \text{Variance}_{\text{Group 3}}$$
$$H_a: \text{Variance}_{\text{Group 1}} \neq \text{Variance}_{\text{Group 2}} \neq \text{Variance}_{\text{Group 3}}$$

Similarly, we expect a p-value from the homogeneity of variance test to be higher than .05 so that we can fail to reject the null hypothesis indicating that variances among all groups are equal.

Performing ANOVA in SPSS

The example that we will use for ANOVA is the comparison of mean salary among people with different levels of education. As mentioned in the beginning of the chapter that nowadays more and more people decide to pursue higher education in hope that they can get better career and better salary, it would be interesting to find some empirical evidence to prove whether people who have higher education actually make more money or not. So let's use ANOVA to obtain the answer.

The null hypothesis and the alternative hypothesis for this study can be expressed as the following:

$$H_0: \text{Salary}_{\text{Below bachelor}} = \text{Salary}_{\text{Bachelor}} = \text{Salary}_{\text{Master}} = \text{Salary}_{\text{Doctoral}}$$
$$H_a: \text{Salary}_{\text{Below bachelor}} \neq \text{Salary}_{\text{Bachelor}} \neq \text{Salary}_{\text{Master}} \neq \text{Salary}_{\text{Doctoral}}$$

In particular, the null hypothesis states that there is no difference in average salary among all four levels of education, whereas the alternative hypothesis states that at least one pair of them will have unequal average salary.

To being using SPSS to perform ANOVA, select **Analyze**
… Compare Means
… One-Way ANOVA
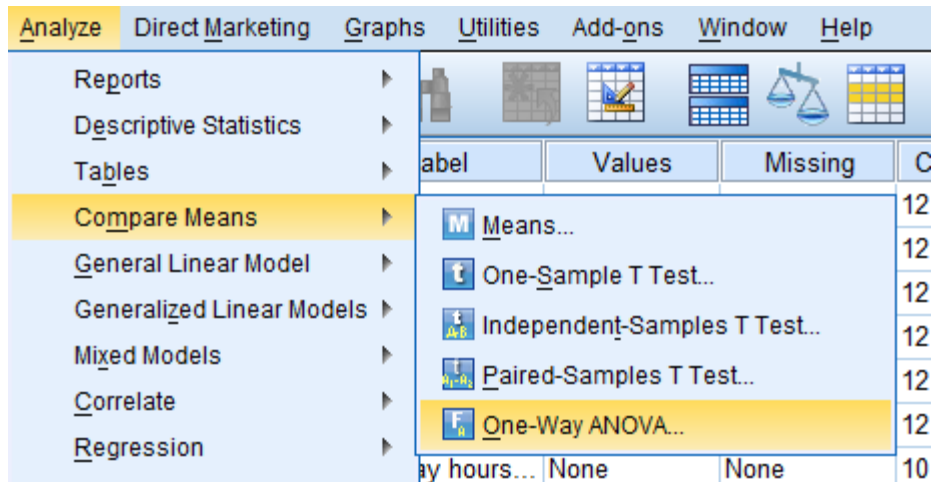
The box "Dependent List" is the place where we put a continuous variable that we want to compare means. In this case, because we want to compare salary, we put the variable 'SALARY' in it. Next, the field "Factor" below is place where we have to indicate the group that we want to compare means. Because we aim to compare salary among people with different educational level, we put a categorical variable 'EDU' in it.
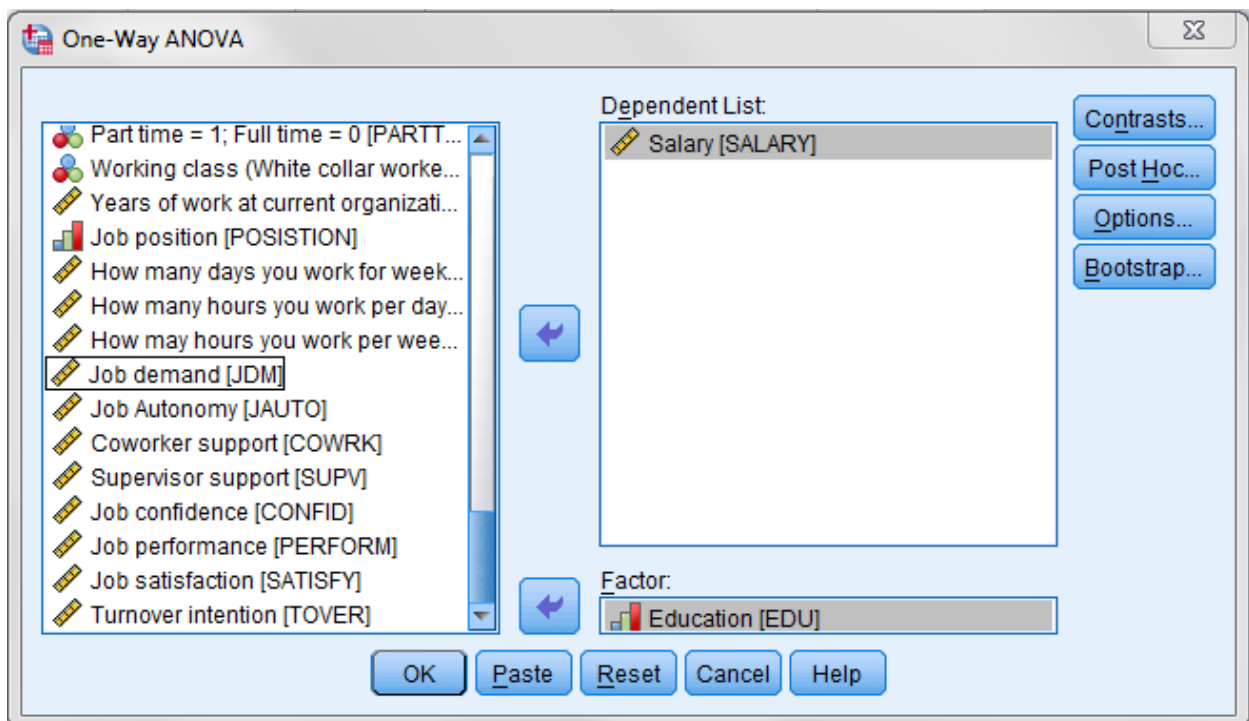
For ANOVA, the indicators of Levene's Test for equality of Variances are not automatically reported like when you performed independent samples t-test. To get the indictors, you have to click the "Options" button. Then in the new pop-up window, you have to check the box "Homogeneity of variances test" to tell SPSS to provide the indicators.
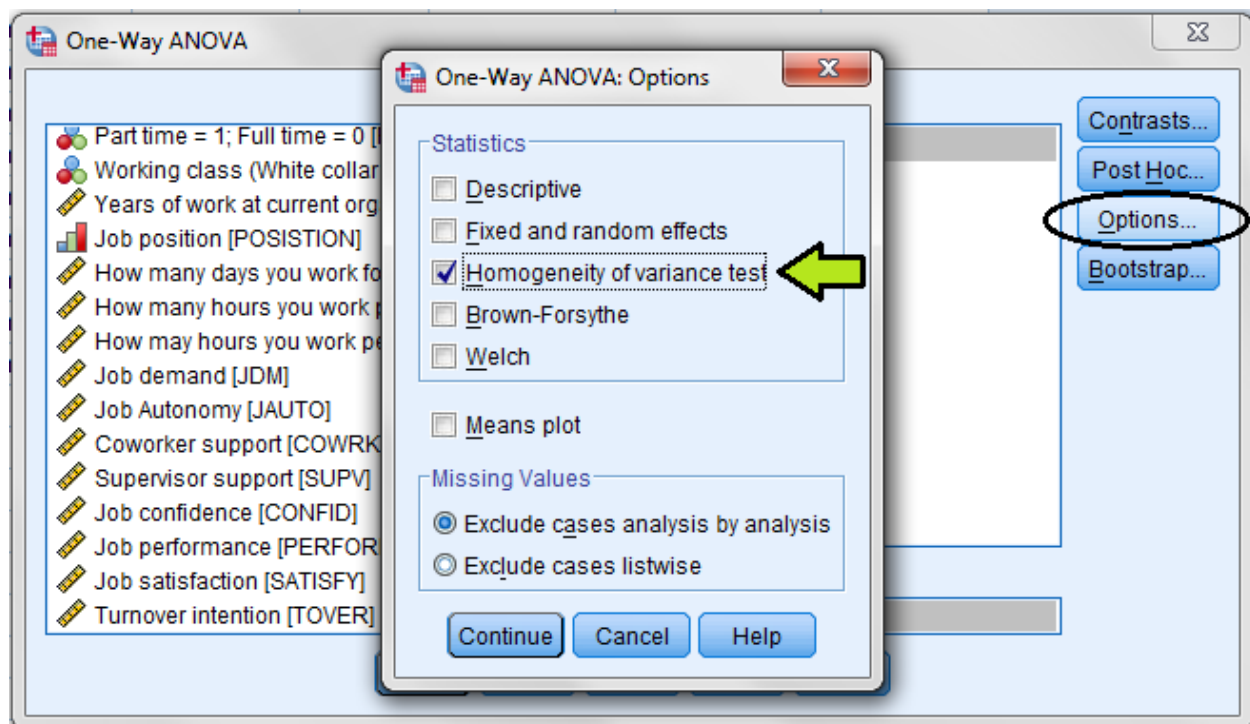
Finally, you have to select the method that will be used to compare means. First, you have to click "Post Hoc" button, then the pop-up window that lists all methods will appear. These methods are classified into two groups: *equal variances assumed* and *equal variances not assumed*. According to Green and Salkind (2003), the method that is generally used when equal variances are assumed is '*Turkey*' and '*R-E-G-W-Q*'; the method that is generally used when equal variances are not assumed is '*Dunnett's C*'. Right now we don't know yet whether the variances in data among the groups that we are comparing are equal or not. So we first select '*Turkey*' for equal variances and '*Dunnett's C*' for unequal variances. We will decide later which method we will use for interpretation after we get the confirmation from the equality of variances test.
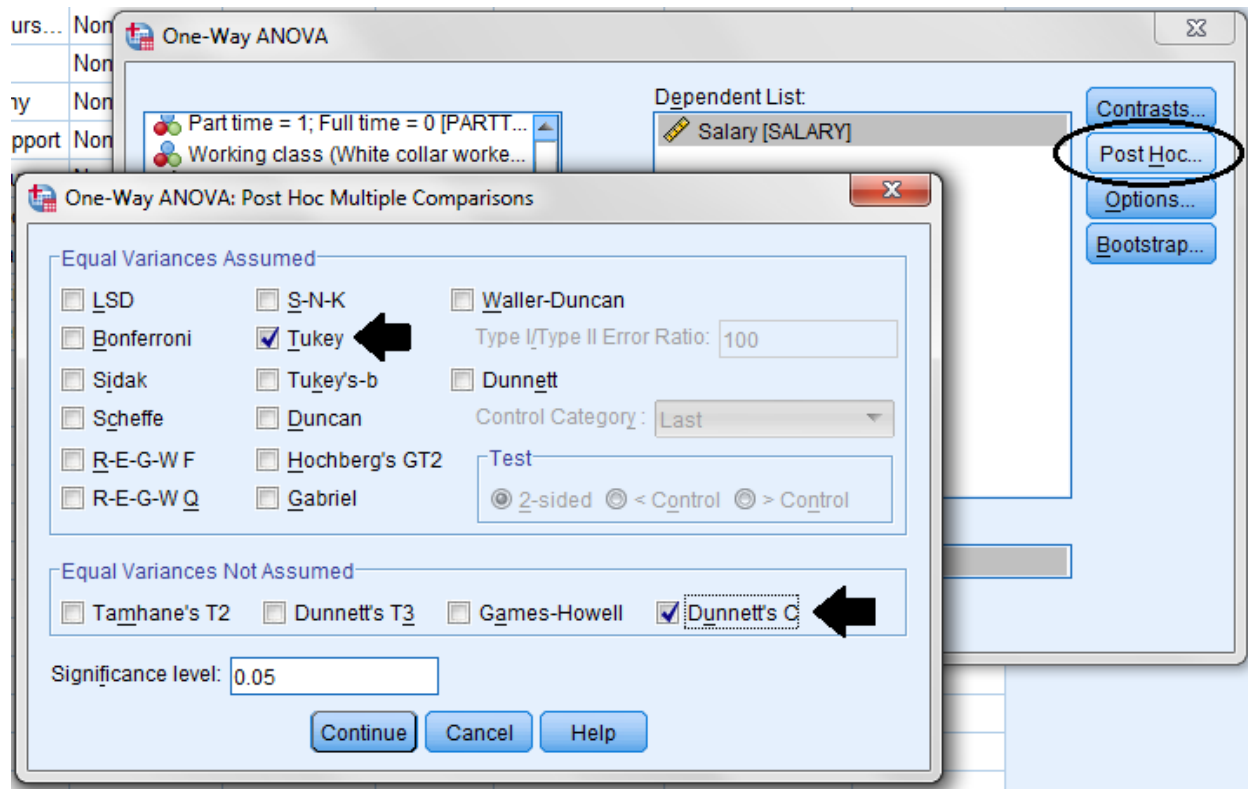
After you perform the analysis, the first table that you will get in the output window is the test of homogeneity of variances. This table tells us whether variances in the data among all groups are equal or not.

Test of Homogeneity of Variances

Salary

Levene Statistic	df1	df2	Sig.
5.720	3	82	.001

From the table, we can move to the last column (Sig) that shows the p-value of the Levene Statistic. In particular, the p-value is .001 which is lower than the .05. It is statistically significant at the 1 percent level. When referring to null hypothesis and the alternative hypothesis of the homogeneity of variances test, the p-value that is lower than or equal to .05 tells us that we can reject null hypothesis which declares that variances among all groups are equal. This means that the alternative hypothesis indicating that variances are unequal is statistically supported. Now we

know that we cannot assume that variances are equal when we interpret the results from ANOVA.

The next table that we got reports the results from ANOVA test. We can move quickly to the last column (Sig) that presents a p-value of the F-statistics that is used in ANOVA. It shows that a p-value is .000 which is greatly lower than .05. In this case, a p-value is statistically significant at the .01 level. This tells us that we can reject the null hypothesis which states the equality of mean. When we reject the null hypothesis, the alternative hypothesis indicting that at least one pair of groups have unequal means is automatically supported.

ANOVA

Salary

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20109223112	3	6703074371	11.354	.000
Within Groups	48410901127	82	590376843.0		
Total	68520124239	85			

Anyway, how can we know which groups have higher or lower income than one another? In particular, the results from ANOVA table do not tell us specifically which groups have higher or lower means than one another. In order to obtain this information, you have to move to the table titled 'Multiple Comparisons' which reports pair-by-pair comparisons between the groups that we have in the analysis.

Multiple Comparisons

Dependent Variable: Salary

	(I) Education	(J) Education	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	Below Bachelor's degree	Bachelor's degree	-25175.815*	6837.649	.002	-43107.59	-7244.04
		Master's degree	-29777.250*	6685.803	.000	-47310.81	-12243.69
		Doctoral degree	-44349.250*	8951.121	.000	-67823.62	-20874.88
	Bachelor's degree	Below Bachelor's degree	25175.815*	6837.649	.002	7244.04	43107.59
		Master's degree	-4601.435	7020.230	.913	-23012.03	13809.16
		Doctoral degree	-19173.435	9203.599	.167	-43309.93	4963.06
	Master's degree	Below Bachelor's degree	29777.250*	6685.803	.000	12243.69	47310.81
		Bachelor's degree	4601.435	7020.230	.913	-13809.16	23012.03
		Doctoral degree	-14572.000	9091.356	.383	-38414.14	9270.14
	Doctoral degree	Below Bachelor's degree	44349.250*	8951.121	.000	20874.88	67823.62
		Bachelor's degree	19173.435	9203.599	.167	-4963.06	43309.93
		Master's degree	14572.000	9091.356	.383	-9270.14	38414.14
Dunnett C	Below Bachelor's degree	Bachelor's degree	-25175.815*	4735.843		-38272.13	-12079.50
		Master's degree	-29777.250*	6155.593		-46735.24	-12819.26
		Doctoral degree	-44349.250*	13799.856		-87251.23	-1447.27
	Bachelor's degree	Below Bachelor's degree	25175.815*	4735.843		12079.50	38272.13
		Master's degree	-4601.435	6894.823		-23663.95	14461.08
		Doctoral degree	-19173.435	14145.080		-62940.41	24593.54
	Master's degree	Below Bachelor's degree	29777.250*	6155.593		12819.26	46735.24
		Bachelor's degree	4601.435	6894.823		-14461.08	23663.95
		Doctoral degree	-14572.000	14681.499		-59625.42	30481.42
	Doctoral degree	Below Bachelor's degree	44349.250*	13799.856		1447.27	87251.23
		Bachelor's degree	19173.435	14145.080		-24593.54	62940.41
		Master's degree	14572.000	14681.499		-30481.42	59625.42

*. The mean difference is significant at the 0.05 level.

Now, let's refer back to the result from the equality of variance test that we obtained earlier. As we already knew that variances among all groups are unequal, we have to use the results under Dunnett' C method to make a decision. By looking at the first column, it shows two groups that are marked by I and J. To determine which group has higher or lower mean, you have to look at the column Mean Difference (I-J). In fact, this column reports the mean difference between group I and group J. If the mean of group I is higher than the mean of group J, the value will be positive; on the other hand, if the mean of group I is lower than the mean of group J, the value will be negative.

If we compare people with below Bachelor's degree (I) with people with Bachelor's degree (J), the column Mean Difference (I-J) indicates that people with below Bachelor's degree earn less than people with bachelor's degree by 25,175 THB (because the sign is negative). However, to conclude whether this mean difference is statistically supported or not, we have to justify by a p-value. In

SPSS, a level of significance of a p-value is also represented by an asterisk mark (*). You may take a look whether there is an asterisk mark (*) behinds the Mean Difference (I-J) or not. If you see one asterisk (*), it means that the p-value is statistically significant at the 5 percent level (p<.05). If you see two asterisk marks (**), it means that the p-value is statistically significant at the 1 percent level (p<.01). Here, the mean difference between people with below Bachelor's degree and people with bachelor's degree of 25,175 THB has one asterisk after it. This means that the mean difference is statistically significant at the 1 percent level. In conclusion, the result indicating that people with below Bachelor's degree tend to earn less than people with Bachelor's degree by 25,175 THB is statistically supported.

How about mean salary difference between people with below Bachelor's degree and people with Master degree? The column Mean Difference (I-J) indicates that people with below Bachelor's degree earn less than people with Master's degree by 29,777 THB (because the sign is negative). Here, one asterisk mark behind the number means that the mean difference is statistically significant at the 5 percent (p<.05). Lastly, how about mean difference between people with below Bachelor's degree and people with Doctoral degree? The column Mean Difference (I-J) indicates that people with below Bachelor's degree earn less than people with Doctoral degree by 44,349 THB (because the sign is negative). One asterisk mark behind the number suggests that the mean difference is statistically significant at the 5 percent level (p<.05). In conclusion, the result indicating that people with below Bachelor's degree tend to earn less than people with Doctoral degree by 44,349 THB is statistically supported.

Now we already know that people with doctoral degree tends to earn more than people with below Bachelor's degree; and this result is statistically supported, let's see quickly whether people with doctoral degree tend to earn more than people with Bachelor's degree and Master degree or not. From the table, you can see that on average people with doctoral degree earn more than people with Bachelor's degree by 19,173 THB and more than people with Master degree by 14,572 THB. However, there no asterisk mark associated with the mean differences. When there is no asterisk mark, it implies that the p-value is greater than .05, thereby indicating that the mean differences that we got are not statistically significant. So although

people with doctoral degree tend to earn more than people with Bachelor's degree and Master's degree, a p-value that is not statistically significant even at the 5 percent level implies that these mean differences may just happen by chance. Similarly, when you compare mean salary between people with Master's degree and people with Bachelor's degree, also the result shows that people with Master's degree earn salary on average more than people with Bachelor's degree by 4,601 THB, this mean difference is not statistically significant. So we cannot conclude by statistics that people with Master's degree earn salary on average than people with Bachelor's degree.

So in conclusion, the results from ANOVA provide empirical evidence that people who have education below Bachelor's degree tend to earn salary significantly less than people with Bachelor's degree, Master's degree, and Doctoral degree. This suggests people may need to get Bachelor's degree for a chance to make more money in their career. However, there is no supported evidence that people who get Master's degree and doctoral degree tend to earn salary significantly higher than people with Bachelor's degree. Also, people who got doctoral degree are not shown to have higher salary than people who finished Master's degree. The overall findings suggest that although getting a Bachelor's degree is important, getting higher education may not necessary determine whether people can earn more money in their career.

References

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