Chp70-1. Evaluate the profit comparison of four e-commerce website designs A/B/C/D. Which pairs of designs have significant differences when the samples conform to a normal distribution and the variances are equal?

(Using SPSS software for analysis, Shapiro–Wilk normality test + ANOVA test + Tukey HSD post-hoc test)

(1). [Concept]: The complexity and difficulty of One-Way ANOVA: It has 3 basic assumptions.

3 basic assumptions of One-Way ANOVA:

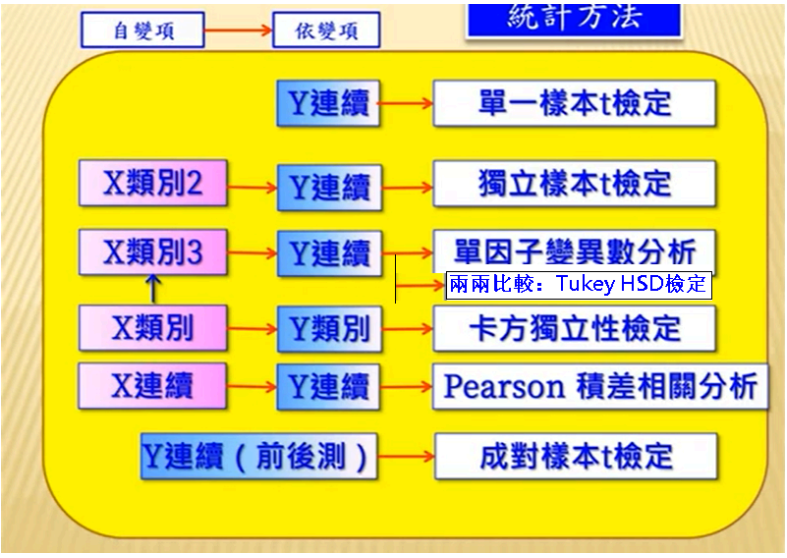
1. Each group of samples is independent

2. Each sample comes from a normally distributed population

3. The variances of each population are equal

(2). [Statistical Test Judgment Schematic Diagram]: Basic diagram, advanced diagram

2-1 Basic diagram



2-2 Advanced diagram (ANOVA test)

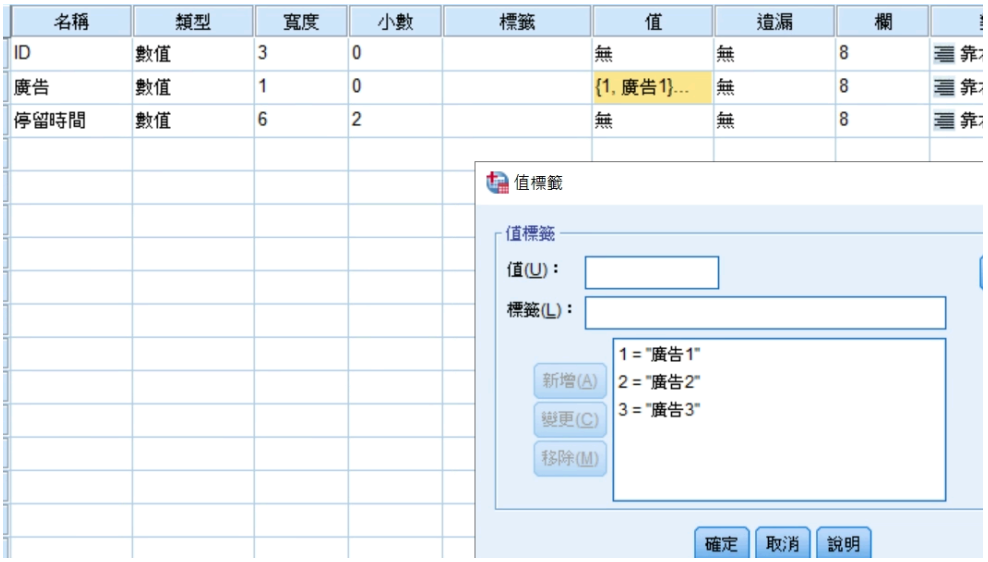
✅ 單因子變異數分析（One-Way ANOVA）檢定流程與事後檢定對照表

狀況	建議方法	事後檢定方式（Post Hoc Test）
母體 ≥ 3，常態分布、變異數相等	One-Way ANOVA	**Tukey HSD**（最常用）、Bonferroni、Scheffé
母體 ≥ 3，常態分布、變異數不等	Welch ANOVA	**Games-Howell**（適用變異數不齊）
母體 ≥ 3，非常態分布	Kruskal-Wallis Test	**Dunn's Test**（需 Bonferroni 或 Holm 校正）

(3). [SPSS Implementation]: So the first step in doing one-way ANOVA is to check: Does the sample conform to a normal distribution?

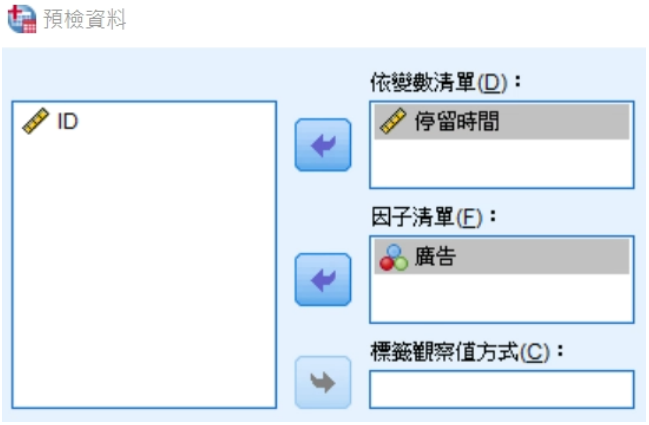
How to perform the Shapiro–Wilk normality test in SPSS

1. **Open SPSS and load the data**

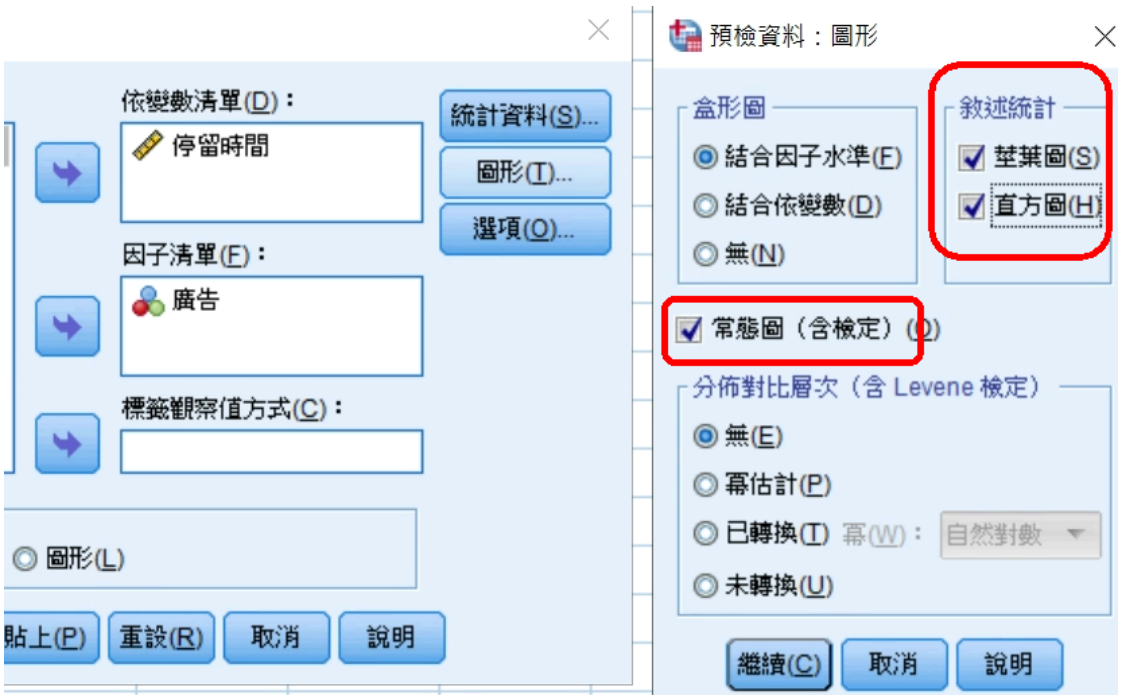


2. **Select the statistical test path**
    - Click Analyze → Descriptive Statistics → Explore.

3. **Set variables**
    - In the Dependent List, select the numerical variable to be tested for normality.
    - In the Factor List, you can select a categorical variable (can be omitted).



4. **Enable normality test**
    - Click the Plots button.
    - On the Descriptive page, check Normality plots with tests.
    - **Make sure the Shapiro-Wilk test is included (**
    - **SPSS automatically calculates Shapiro-Wilk when the sample size is less than 50,**
    - **Kolmogorov-Smirnov test is provided when the sample size exceeds 50).**



How to interpret the results

- In the output Tests of Normality table:
  - **Shapiro–Wilk's p-value (Sig.)**
    - If p > 0.05, it means that the data follows a normal distribution.
    - If p ≤ 0.05, it means that the data deviates significantly from the normal distribution.

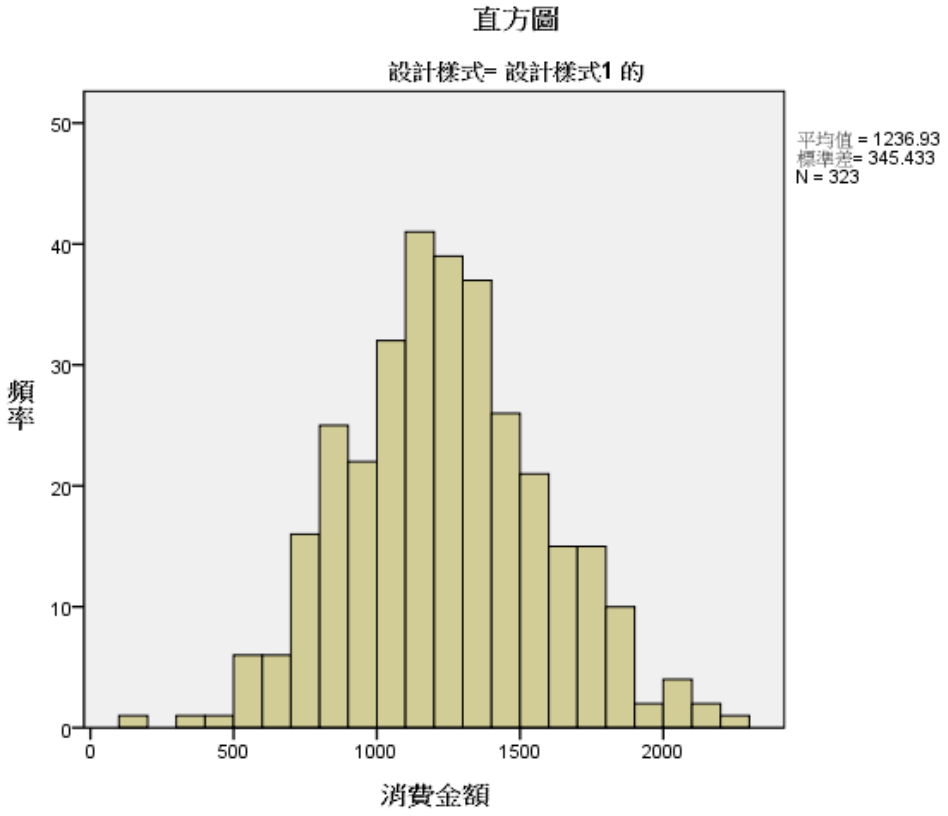
常態檢定

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	設計樣式	統計量	自由度	顯著性	統計量	自由度	顯著性
消費金額	設計樣式1	.035	323	.200*	.996	323	.684
	設計樣式2	.045	325	.200*	.995	325	.356
	設計樣式3	.033	330	.200*	.997	330	.897
	設計樣式4	.046	325	.094	.996	325	.536

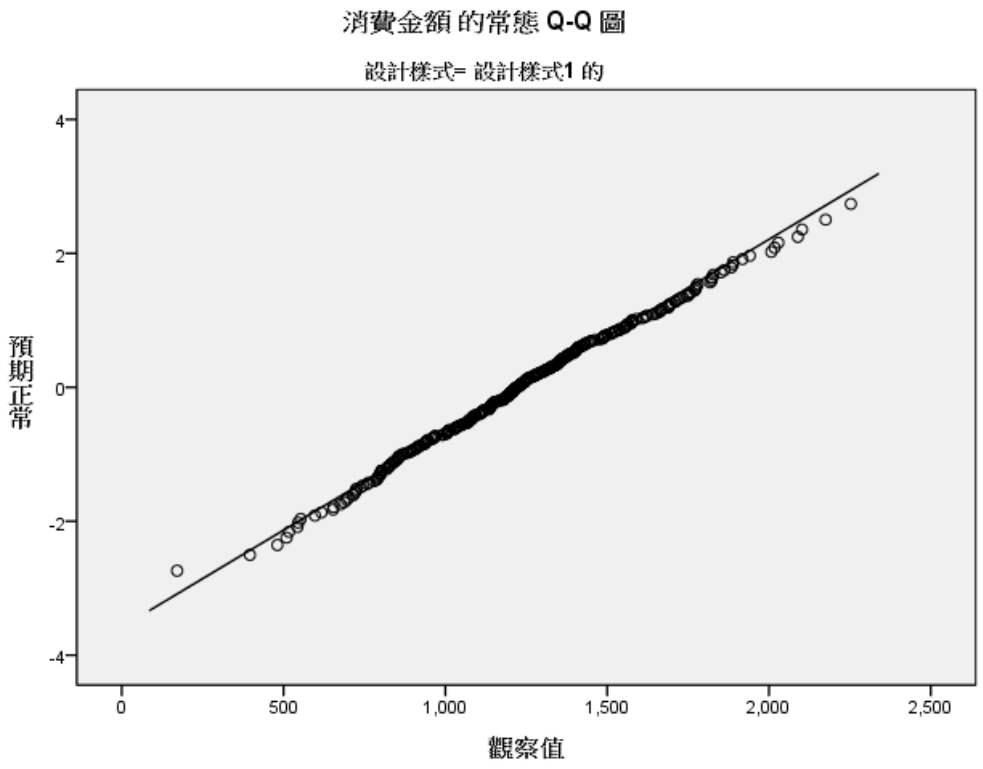
Conclusion: Because the sample size is 450, look at the [Kolmogorov-Smirnov test]

Significance p-value > 0.05, so it means that the data conforms to a normal distribution

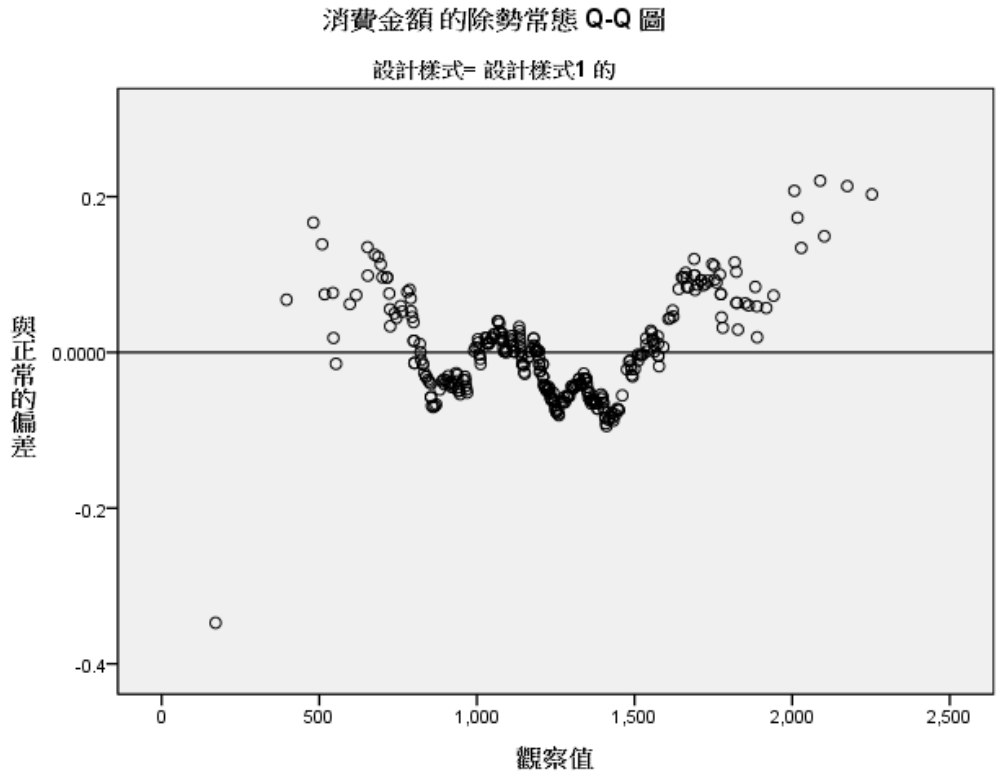
Graphical proof 1: Histogram



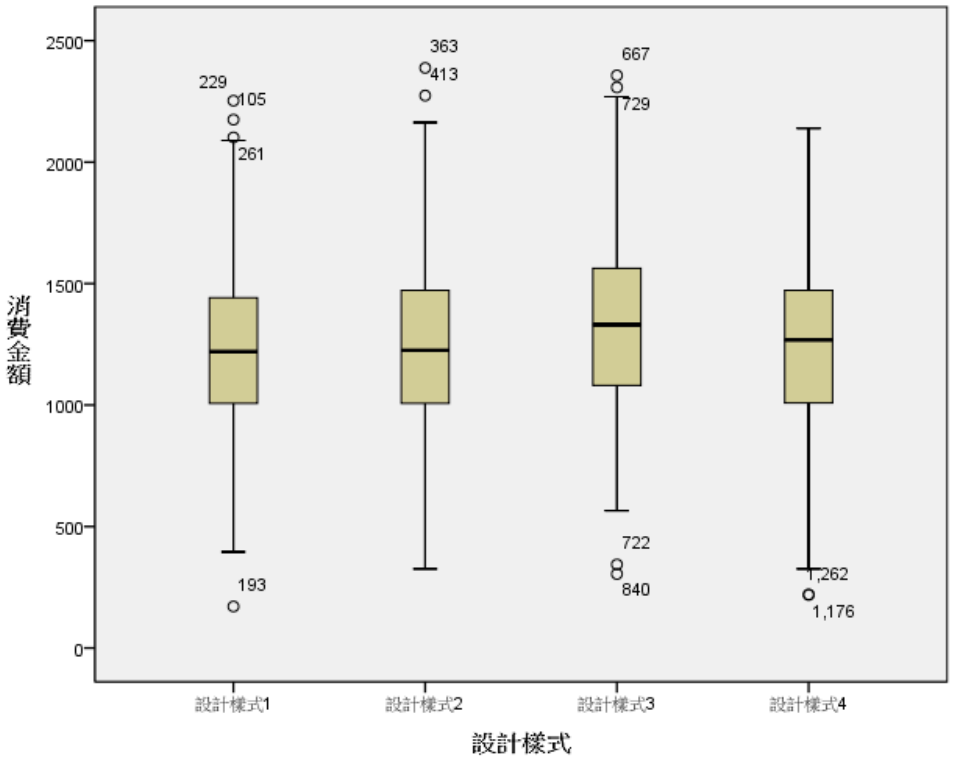
Graphical proof 2: QQ plot (data must be on a straight line to be normally distributed)



Graphical proof 3: Detrended QQ plot (data must be close to the horizontal 0 axis to be normally distributed)



Graphical proof 4: Box plot (data must not have outliers outside the quartiles to be normally distributed)



(4). [Concept]: If the data conforms to a normal distribution and the variances are not equal, ANOVA test can be used, Welch ANOVA test cannot be used

3 basic assumptions of One-Way ANOVA:

1. Each group of samples is independent

2. Each sample comes from a normally distributed population

3. The variances of each population are equal

Advanced diagram (ANOVA test)

✅ 單因子變異數分析（One-Way ANOVA）檢定流程與事後檢定對照表

狀況	建議方法	事後檢定方式（Post Hoc Test）
母體 ≥ 3，常態分布、變異數相等	One-Way ANOVA	Tukey HSD（最常用）、Bonferroni、Scheffé
母體 ≥ 3，常態分布、變異數不等	Welch ANOVA	Games-Howell（適用變異數不齊）
母體 ≥ 3，非常態分布	Kruskal-Wallis Test	Dunn's Test（需 Bonferroni 或 Holm 校正）

(5). [SPSS Implementation]: ANOVA test

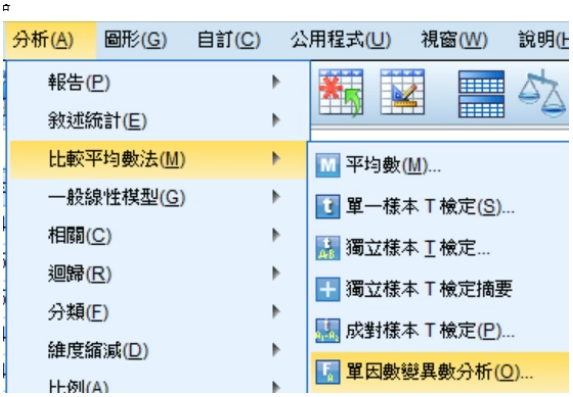
When processing 3 groups of population samples in SPSS, if you want to perform one-way ANOVA, you must check whether the variances are equal (homogeneity of variance) before the formal analysis.

This check is usually performed through Levene's Test.

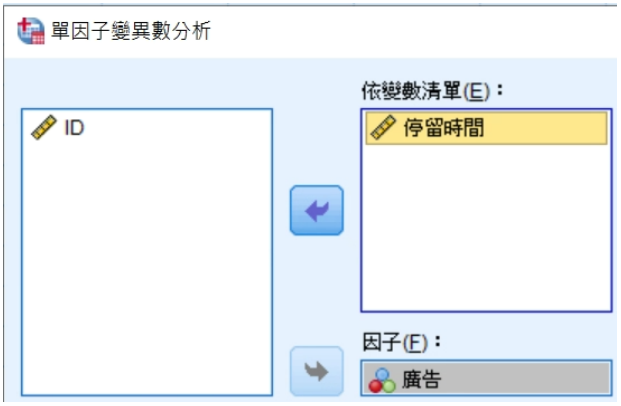
✅ SPSS steps to check whether the variances are equal (Levene's Test)

📌 SPSS Operation Steps:

1. **Open the data file**
2. **Click the menu: Analyze → Compare Means → One-Way ANOVA**



3. **In the pop-up window:**
    - **Put the continuous variable into "Dependent List"**
    - **Put the categorical variable into "Factor"**



4. **Click the [Options] on the right**
    - **Check "Homogeneity of variance test"**
    - **You can also check "Descriptive"**

📋 **Interpretation of output results (Levene's Test):**

In the SPSS output table, you will see a block labeled: Test of Homogeneity of Variances

Including:

- **F value, df1, df2, Sig. (p value)**

變異數同質性檢定

消費金額

Levene 統計量	自由度 1	自由度 2	顯著性
.065	3	1299	.979

🧠 判讀原則：

Levene's Test 結果	判斷	說明
p ≥ 0.05	**變異數相等**（等變異）	可使用 One-Way ANOVA
p < 0.05	**變異數不等**（不齊性）	不宜使用傳統 ANOVA，建議改用 **Welch ANOVA**

Conclusion: Because the significance p-value 0.979 > 0.05,

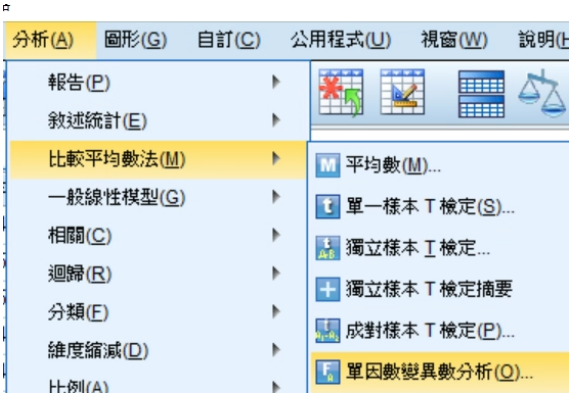
So it means: the variances are equal, use Anova, do not use Welch Anova

(5). [SPSS Implementation]: ANOVA test

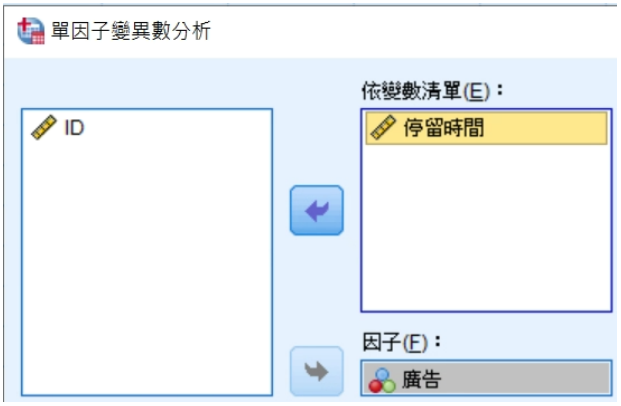
SPSS provides ANOVA as an option for One-Way ANOVA.

Steps

1. **Open SPSS and load the data**
2. **Select ANOVA**
    - **Click Analyze → Compare Means → One-Way ANOVA.**



3. **Set variables**
    - **Dependent List: Select the continuous variable to be compared (such as test scores, income, etc.).**
    - **Factor: Select the categorical variable (such as group).**



How to interpret ANOVA results

In the output "Robust Tests of Equality of Means" table:

- **Test p-value (Sig.)**
    - **p > 0.05: No significant difference between groups.**
    - **p ≤ 0.05: At least one group's mean is significantly different from other groups.**

變異數分析

消費金額

	平方和	自由度	均方	F	顯著性
群組之間	1873468.605	3	624489.535	5.211	.001
群組內	155681522.5	1299	119847.207		
總計	157554991.1	1302			

Conclusion: Because the significance p-value 0.00 < 0.05,

So it means: At least one group's mean is significantly different from other groups

(6). [Implementation]: [Post-hoc Test: Tukey HSD test]

- **Tukey HSD test Post-hoc Test**

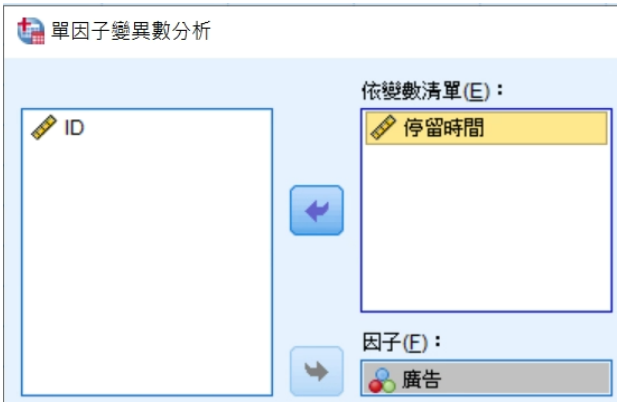
How to perform the Tukey HSD test in SPSS

Tukey HSD post-hoc test can be performed through One-Way ANOVA.

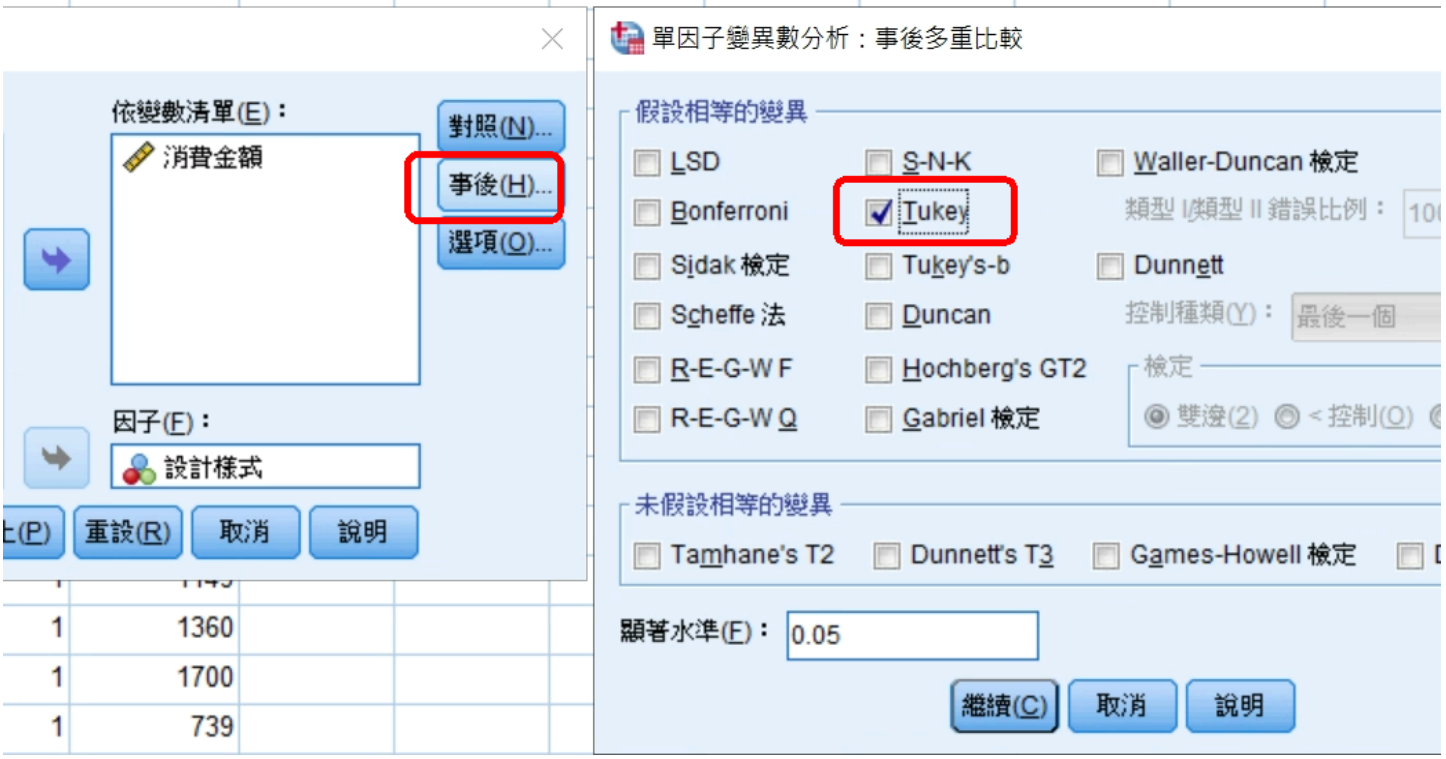
Steps

1. **Open SPSS and load the data**
2. **Select One-Way ANOVA**
   - Click Analyze → Compare Means → One-Way ANOVA.

3. **Select variables**
   - **Dependent List: Select the numerical variable to be compared (such as scores, measurements).**
   - **Factor: Select the categorical variable used for grouping (such as different groups).**



4. **Enable Tukey HSD post-hoc test**
    - Click the Post Hoc button.
    - In the Equal Variances Not Assumed area, check Tukey HSD test.



How to interpret SPSS Tukey HSD test results

SPSS will output a "Multiple Comparisons" table, where:

- **Mean Difference: Shows the mean difference between two groups.**
- **Std. Error: Estimated error.**
- **Sig. (significance p-value):**
    - **$p > 0.05$: No significant difference between the two groups.**
    - **$p \leq 0.05$: There is a significant difference between the two groups.**

多重比較

依變數: 消費金額

Tukey HSD

(I) 設計樣式	(J) 設計樣式	平均值差異 (I-J)	標準誤	顯著性	95% 信賴區間	
					下限	上限
設計樣式1	設計樣式2	-3.576	27.199	.999	-73.54	66.39
	設計樣式3	-93.274*	27.096	.003	-162.98	-23.57
	設計樣式4	-19.607	27.199	.889	-89.57	50.36
設計樣式2	設計樣式1	3.576	27.199	.999	-66.39	73.54
	設計樣式3	-89.698*	27.054	.005	-159.29	-20.11
	設計樣式4	-16.031	27.157	.935	-85.89	53.83
設計樣式3	設計樣式1	93.274*	27.096	.003	23.57	162.98
	設計樣式2	89.698*	27.054	.005	20.11	159.29
	設計樣式4	73.668*	27.054	.033	4.07	143.26
設計樣式4	設計樣式1	19.607	27.199	.889	-50.36	89.57
	設計樣式2	16.031	27.157	.935	-53.83	85.89
	設計樣式3	-73.668*	27.054	.033	-143.26	-4.07

***See [Significance p-value]**

1. [For design style 1] ➜ See if the significance value is < 0.05
➜ [Only design style 3 has a p-value of 0.003 < 0.05]
➜ Indicates [There is a significant difference in the effect between designs 1/3]

2. [For design style 2] ➜ See if the significance value is < 0.05
➜ [Only design style 3 has a p-value of 0.005 < 0.05]
➜ Indicates [There is a significant difference in the effect between designs 2/3]

3. [For design style 3] ➜ See if the significance value is < 0.05
➜ [Only design style 3 has a p-value of 0.003 < 0.05]
➜ Indicates [There is a significant difference in the effect between designs 3/1, 2, 4]

4. [For design style 4] ➜ See if the significance value is < 0.05

➜ [Only design style 3 has a p-value of 0.033 < 0.05]
➜ Indicates [There is a significant difference in the effect between designs 4/3]

(5-3). Step 2 Conclusion:

1. [Conclusion 1]: For the original design [design style 1], The improved [3rd design] can best increase the [sales amount] to [93.274] yuan, which is the highest. The range of increase (upper limit, lower limit) is [23.57～162.98]

2. [Conclusion 2]: For the original design [design style 1], The improved [2nd, 4th design] is not the best. Although it can increase the [upper limit, lower limit] of the [sales amount], it may be [positive] or [negative], so the improvement effect is not significant (therefore p-value > 0.05)

3. [Conclusion 3]: Use [tukey HSD test] to observe the [upper limit, lower limit, average difference] between the [design style 3 vs original design style 1] with the highest effect, Let the [manager] know that the [sales amount can be increased by an average of 93.274] after modifying the design, so that the [time to recover the cost] can be roughly calculated

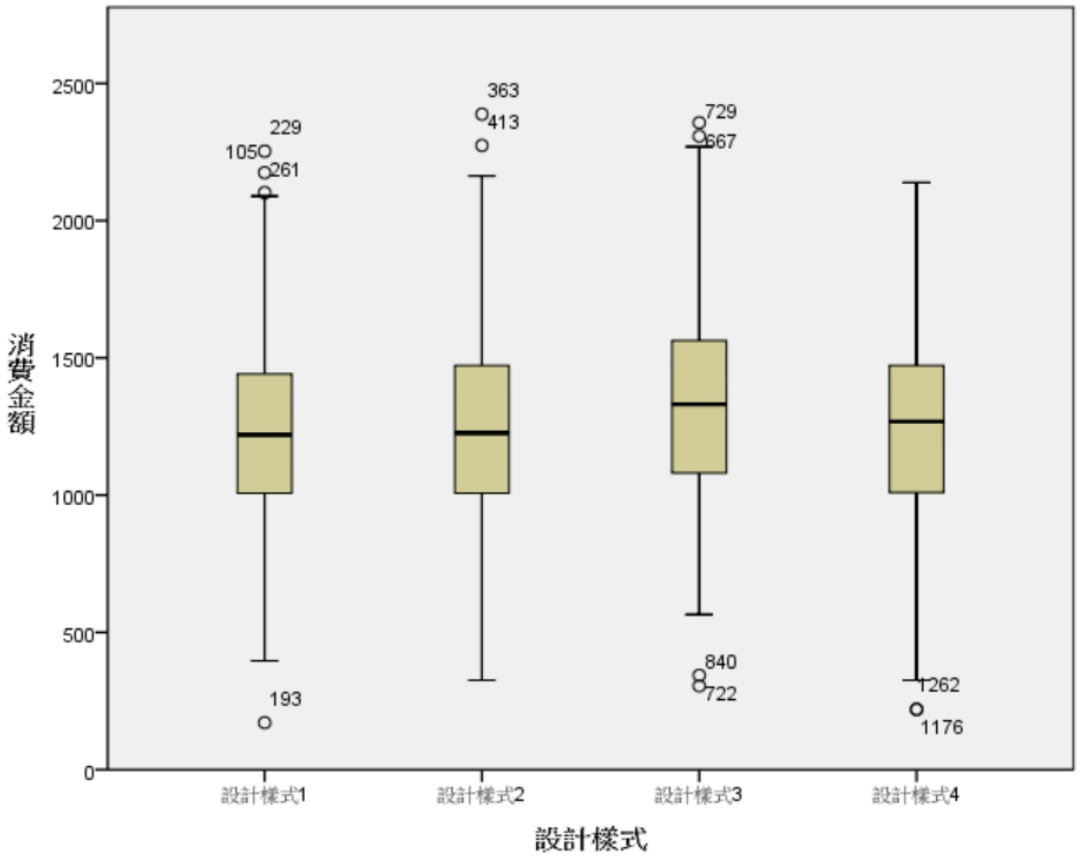
4. [Conclusion 4]: Use [tukey HSD test] to observe the [upper limit, lower limit, average difference] between the [design style 2, 4] vs [original design style 1] with the second highest effect. Although the average value has increased, the [upper limit, lower limit] oscillates between [positive value ~ negative value], so it cannot be guaranteed to increase the [sales amount], so it is not included in the design consideration (because p-value > 0.05)

5. [Conclusion 5]: Make a [Recommendation table of A/B/C/D plans]

網站設計種類	平均銷售金額	建議採用順序
設計3	1330	1
設計4	1256	2
設計2	1240	3
設計1(原本設計)	1236	4

(7). [Drawing]: Box plot

GGraph



(8). [Drawing]: Line chart