STAT 314

Preliminary research on the production of imitation pearls entailed studying the effect of the number of coats of a special lacquer applied to an opalescent plastic bead used as the base of the pearl on the market value of the pearl. Four batches of beads (12 beads per batch) were used in the study, and it is desired to also consider the batch effect on the market value. The three levels of lacquer coatings (6, 8, and 10 coats) were fixed in advance, as were the production formulations for the four batches. The market value of each pearl was determined by a panel of experts. The data are shown in the accompanying table. Perform the appropriate analysis of variance procedure (including a profile plot of the means, hypothesis tests, and multiple comparisons) for this experiment. Use $\alpha = 0.05$.

Number	Batch						
of Coats	1	2	3	4			
6	72.0	72.1	75.2	70.4			
	74.6	76.9	73.8	68.1			
	67.4	74.8	75.7	72.4			
	72.8	73.3	77.8	72.4			
8	76.9	80.3	80.2	74.3			
	78.1	79.3	76.6	77.6			
	72.9	76.6	77.3	74.4			
	74.2	77.2	79.9	72.9			
10	76.3	80.9	79.2	71.6			
	74.1	73.7	78.0	77.7			
	77.1	78.6	77.6	75.2			
	75.0	80.2	81.2	74.4			

1. Each treatment is a combination of the Number of Coats value and the Batch value. Enter the treatment numbers into one column with the corresponding number of coats, batch number, and market values into separate variables (*see figure, below*). Be sure to enter your variables appropriately.

	treatment	factor_A	factor_B	value
1	Treatment 1	6 Coats	Batch 1	72.0
2	Treatment 1	6 Coats	Batch 1	74.6
3	Treatment 1	6 Coats	Batch 1	67.4
4	Treatment 1	6 Coats	Batch 1	72.8
5	Treatment 2	6 Coats	Batch 2	72.1
6	Treatment 2	6 Coats	Batch 2	76.9
- 7	Treatment 2	6 Coats	Batch 2	74.8
8	Treatment 2	6 Coats	Batch 2	73.3
9	Treatment 3	6 Coats	Batch 3	75.2
10	Treatment 3	6 Coats	Batch 3	73.8
11	Treatment 3	6 Coats	Batch 3	75.7
12	Treatment 3	6 Coats	Batch 3	77.8
13	Treatment 4	6 Coats	Batch 4	70.4
14	Treatment 4	6 Coats	Batch 4	68.1
15	Treatment 4	6 Coats	Batch 4	72.4
16	Treatment 4	6 Coats	Batch 4	72.4
17	Treatment 5	8 Coats	Batch 1	76.9
18	Treatment 5	8 Coats	Batch 1	78.1
19	Treatment 5	8 Coats	Batch 1	72.9
20	Treatment 5	8 Coats	Batch 1	74.2
21	Treatment 6	8 Coats	Batch 2	80.3
22	Treatment 6	8 Coats	Batch 2	79.3
23	Treatment 6	8 Coats	Batch 2	76.6
24	Treatment 6	8 Coats	Batch 2	77.2
25	Treatment 7	8 Coats	Batch 3	80.2
26	Treatment 7	8 Coats	Batch 3	76.6
27	Treatment 7	8 Coats	Batch 3	77.3
28	Treatment 7	8 Coats	Batch 3	79.9
29	Treatment 8	8 Coats	Batch 4	74.3
30	Treatment 8	8 Coats	Batch 4	77.6
31	Treatment 8	8 Coats	Batch 4	74.4
32	Treatment 8	8 Coats	Batch 4	72.9
33	Treatment 9	10 Coats	Batch 1	76.3
34	Treatment 9	10 Coats	Batch 1	74.1
35	Treatment 9	10 Coats	Batch 1	77.1
36	Treatment 9	10 Coats	Batch 1	75.0
37	Treatment 10	10 Coats	Batch 2	80.9
38	Treatment 10	10 Coats	Batch 2	73.7
39	Treatment 10	10 Coats	Batch 2	78.6
40	Treatment 10	10 Coats	Batch 2	80.2
41	Treatment 11	10 Coats	Batch 3	79.2
42	Treatment 11	10 Coats	Batch 3	78.0
43	Treatment 11	10 Coats	Batch 3	77.6
44	Treatment 11	10 Coats	Batch 3	81.2
45	Treatment 12	10 Coats	Batch 4	71.6
46	Treatment 12	10 Coats	Batch 4	77.7
47	Treatment 12	10 Coats	Batch 4	75.2
48	Treatment 12	10 Coats	Batch 4	74.4

2. Now it is time to check the normality assumption [this won't work if you have *m* = 1 observation per treatment combination]. Select "Split File" from the "Data" menu so that we can tell SPSS that we want separate Q–Q Plots for each treatment group *(see left figure, below)*. Select "Organize output by groups" and enter "treatment" as the variable that groups are based upon *(see right figure, below)*. Now click "OK".

Data Transform Analyze Graphs U	Split File		
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New Custom Attribute	Batch Ifactor B1		
Define Dates	Andres Value [ushed]	Compare groups	Paste
Define Multiple Response Sets	Market value [value]	 Organize output by groups 	
Identify Duplicate Cases		Groups Based on:	Reset
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Restructure			
Merge Files 🕨 🕨			
Aggregate		Sort the file by grouping variables	
		File is already sorted	
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Split File			
Select Cases			
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Brighter e ministere e Liez			

You can create separate Normal Q–Q Plots to assess the normality of each treatment group *(see separate handout on Normal Q–Q Plots)*, or you can create a single matrix of Normal Q–Q Plots using the following procedure (a single matrix plot takes up much less space than many separate Normal Q–Q Plots.

Select "Rank Cases..." from the "Transform" menu *(see left figure, below)*. Enter "Market Value" as the variable and rank the cases by "Treatment" *(see middle figure, below)*. Click the "Rank Types..." button and be sure that "Normal scores" and "Blom" are selected in the resulting window, then click the "Continue" button *(see right figure, below)*. Now click "OK".

Compute Variable Count Values within Cases Recode into Same Variables	Number of Coats [fact-	Variable(s): 🔗 Market Value [value]	ОК	Rank Cases: Types	
Recode into Same Variables	Batch [factor_B]	A Market Value [Value]			
Recode into Different Variables Automatic Recode Visual Binning Bank Cases		By:	Paste Reset Cancel Help	Rank Fractional rank as % Savage score Sum of case weights Fractional rank Ntiles: Milles: 4	Continue Cancel Help
Date and Time Wizard Create Time Series Replace Missing Values Random Number Generators Pure Barding Transforme Childs	Assign Rank 1 to Smallest value Largest value	Treatment (treatment) Display summary tables Rank Types Ties		Proportion Estimation Formula Proportion Estimation Formula Blom Tukey Rankit Van der Waerden]

Select "Aggregate..." from the "Data" menu *(see left figure, below)*. Enter "Treatment" in the break variable box and "Market Value" in the summaries of variables box (MEAN) will be selected by default *(see middle figure, below)*. Enter "Market Value" in the summaries of variables box again, then click the "Function..." button and select "Standard Deviation" before clicking the "Continue" button *(see right figure, below)*. Now click "OK".

Data Transform Analyze Graphs I	Aggregate Data	×	Ageregate Data: Aggregate Function
Define Variable Properties Copy Data Properties Define Dates Define Multiple Response Sets Identify Duplicate Cases Sort Cases Transpose	Mumber of Cools (Jack Brek/Variable(s) Model Value (pake) Model Value Model V	OK Paste Reset Carcel Help	Summary Statistics Specific Values Number of cases Continue Mean First Weighted missing Cancel Median Last Weighted missing Help Sum Minimum Unweighted missing Help Ø Standard deviation Maximum Unweighted missing Percentages Above Values
Restructure Merge Files •	Save		
Aggregate	Add aggregated variables to active dataset Create a new dataset containing only the aggregated variables Dataset name		Outside
Copy Dataset	Write a new data life containing only the aggregated variables		Above Value:
Weight Cases	Options for Very Large Datasets File is already solited on break variable(s) Solt file before aggregating		Inside Low: High: High:

We have just computed the normal scores for the data values within each treatment group as well as the mean and standard deviation for each treatment group. We will now use these values to compute the expected observed values if the data were normally distributed (these values are what we plot versus the actual observed values in a Normal Q–Q Plot).

Select "Compute Variable..." from the "Transform" menu *(see left figure, below)*. Enter "ExpNormal" as the target variable, and the numeric expression should be "value_mean + (Nvalue * value_sd)" *(see right figure, below)*.

	Compute Variable	\mathbf{X}
	Target Variable: Numeric Expression: ExpNormal = value_mean + [Nvalue * value_sd]	
ransform Analyze Graphs Utilities Add-ons Compute Variable Count Values within Cases Recode into Same Variables Automatic Recode Visual Birning	Type & Label	
Rank Cases Date and Time Wizard Create Time Series Replace Missing Values Random Number Generators	Functions and Special Variabl	es:
Run Pending Transforms Ctrl+G	[If (optional case selection condition)	
	OK Paste Reset Cancel Help	

Since a normal score (z-score or "Nvalue") gives the expected number of standard deviations away from the mean that a data value should fall if it were normal, we compute the expected observed values by determining what value is the z-score number of standard deviations from the mean ($x = \mu + z\sigma$), where the mean and standard deviation are estimated for each treatment group using the corresponding sample mean and sample standard deviation, respectively. Now click "OK".

Once you've created the expected observed values ("ExpNormal"), select "Split File" from the "Data" menu and then select "Analyze all cases, do not create groups" in order to return SPSS to its normal data analysis mode *(see figure, below)*.

Bour Frite Batch (factor_B) Batch (factor_B) Market Value (value) Mormal Score of value Value_mean Value_sd ExpNormal Current Status: Organize out	 Analyze all cases, do not create groups Compare groups Organize output by groups Groups Based or. Treatment [treatment] Soft the file by grouping variables File is already sorted 	Cancel Help
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Select "Scatter/Dot..." from the "Legacy Dialogs" submenu of the "Graphs" menu *(see left figure, below)*. Select "Simple Scatter" then click the "Define" button *(see middle figure, below)*. Enter "ExpNormal" in the Y-Axis box, "Market Value" in the X-Axis box, and panel your plots by "Number of Coats" as the rows and "Batch" as the columns (to match the way the data are presented in the problem description) *(see right figure, below)*. Be sure to click the "Titles..." button and enter "Q-Q Plots by Treatment Groups" as Line 1 of your title.



Once you click "OK", you'll be switched to the output window to see your plots so far (we aren't done quite yet). Now, double-click the graph matrix to open it in editor mode. From the "Options" menu in editor mode, select "Reference Line from Equation" (see left figure, below). Lines should be added to each plot, and the "Properties" window should open. Change the custom equation so that the equation plotted becomes "y = x" (see middle figure, below). You may now exit out of editor mode as your plots now have the proper diagonal line displayed (see right figure, below). The resulting plots can now be interpreted individually in the same manner as Q-Q plots created by the usual method (Analyze \rightarrow Descriptive Statistics \rightarrow Q-Q Plots...) are interpreted.



3. Select Analyze \rightarrow General Linear Model \rightarrow Univariate... (see figure, below).



4. Select "Market Value" as the dependent variable, and select "Number of Coats" (factor_A) and "Batch Number" (factor_B) as the fixed factors (*see figure, below*).



Click the "Model..." button. In the Univariate:Model window, select the "Custom" option and then the pull-down option in the center for "Main effects". Select "factor_A" (Number of Coats) and "factor_B" (Batch) and move them to be in the Model. Next, after changing the pull-down option in the center to "Interaction", select both "factor_A" and "factor_B" and then move them to be in the Model. [*Note:* You will not include this "Interaction" component if you have m = 1 observation per treatment combination.] Also, be sure that "Type III" sum of squares and "Include intercept in model" are selected, and then click "Continue" (*see left figure, below*).

Univariate: Model 🛛 🔀	
Specify Model C full factorial Factors & Covariates: Factor_A factor_B(F) Build Term(e) Interaction V	Univariate: Profile Plots Factors: Factor_A Factor_B Separate Lines: Flots: Flots: Help Flots: Help Flots: Help Flots: Flots: Flo
Sum of squares: Type III V Include intercept in model Continue Cancel Help	factor_B"factor_A

Click the "Plots..." button. In the Profile Plots window, select one factor for the horizontal axis and one for the separate lines (the treatment means will be on the vertical axis). Be sure to click "Add" and then click "Continue" (*see right figure, above*).

Click the "Post Hoc..." button, select the "Tukey" procedure, enter "factor_A" (Number of Coats) and "factor_B" (Batch) as the Post Hoc Tests variables, and click "Continue". Click the "Options..." button, select "Homogeneity tests" [Levene's Test won't work unless $m \ge 3$], enter 0.05 for the significance level (95% CI corresponds to a 5% (0.05) significance level), and click "Continue" (see 2 figures, below). Now click the "OK" button in the main Univariate window.

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		onivariate: options
Inivariate: Post Factor(s): factor_A factor_B	Hoc Multiple Comparisons for Observed Means Post Hoc Tests for Factor A Factor A Factor B Continue Heip	F Estimated Marginal Means Factor(s) and Factor Interactions: [OVERALL] [actor_A] [actor_A] [actor_A] [actor_A] [actor_A] [actor_A] [actor_B] [actor_A] [actor_B] [actor_A] [actor_B] [a
Equal Valiances A LSD Bonferoni Sidak Scheffe R-E-G-W F R-E-G-W Q Equal Valiances N Tamhane's T2	SAURES SAK Waler Duncen Tope I/Tope I/Tope II Error Rato: Toteyris Duncen Duncen Gabriel Gabriel Control Category: Last Control Cont	LSD (none) Display Descriptive statistics Listinates of effect size Estimates of effect size Deserved power Parameter estimates Contrast coefficient matrix General est Stanificance level: 0.05 Confidence intervatas
		Continue

5. Your output should look like this.

Between-	Subjects Factors	s									
	Value Label	N	1								
Number 1	6 Coats	16	1								
or coats 2	8 Coats	16									
Batch 1	Batch 1	12									
2	Batch 2	12									
3	Batch 3	12									
4	Batch 4	12									
Levene's Test of	Equality of Error	Variances									
Dependent Variable	: Market Value	Pia	_								
.4994	11 36	5 .89	09								
Tests the null hypot	hesis that the err	ror variance	ofthe								
dependent variable	is equal across	groups.									
a. Design: Interc	ept+factor_A+fac	tor_B+facto	r_A*factor_B								
D	Tests of	Between-S	ubjects Effect	5							
Dependent Variable	Type III Sum		-	_		_					
Source	of Squares	ar	Mean Squa	re F	Sig	1.					
Corrected Model	305.0917*	11	27.73	56 5.750	8.0	000					
intercept factor A	274397.7633	1	274397.76	33 56894.5	7 .0	000					
factor_B	152.8517		50.95	06 10.564	3 .0	1000					
factor_A * factor_B	1.8521	- E	.30	87 .064	0 .9	988					
Error	173.6250	36	4.82	29							
Total Commente d'Total	274876.4800	48									
Corrected Lotes	478,7167	47									
8. R Squared = 1	537 (Adjusted R	Squared = .	526)	,							
». R Squared = , ost Hoc Tes umber of Co	537 (Adjusted R ts pats	Squared = .	526)								
•. R Squared = . ost Hoc Tes umber of Co	ts bats	Squared = .	526) Multiple Comp	Parisons							
a. R Squared = . ost Hoc Tes umber of Co	537 (Adjusted R ts pats : Market Value	Squared = .	528) Multiple Comp	Darisons							
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R Squared = . ost Hoc Tes umber of Co Dependent Variable Tukey HSD	537 (Adjusted R ts pats :: Market Value	Squared = .	526) Multiple Comp	Datisons				1			
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R Squared = . ost Hoc Tes umber of Cc Dependent Variable Tukey HSD ONumber of Coats @ Coats @ Coats @ Coats	37 (Adjusted R ts) ats : Market Value : (j) Number (8 Coats 10 Coats 8 Coats	Squared = .	Multiple Comp Mean Difference (-J) -3.6875* -3.8188* 2.6975*	Std. Error .7764 .7764	Sig. .0001 .0001	95% Confid Lower Bound -5.5854 -5.716 1.7096	nce Interval Upper Bound -1,7890 -1,9200 5,585-				
R Squared = . ost Hoc Tes umber of Cc Dependent Variable Tukey HSD (i) Number of Coats 8 Coats 8 Coats 10 Coats	537 (Adjusted R ts bats :: Market Value :: (J) Number :: 0 Coats :: 0 Coats :: 10 Coats :	of Coats	Mean Difference (J-3) -3.6875* -3.6875* -3.9195* -3.9195*	Std. Error 7764 7764 7764 7764	Sig. .0001 .0001 .0001 .0001	95% Confid Lower Bound - 5 8854 - 5 7186 - 2 0291 1 9 0700	nce Interval Upper Bound - 1.7894 - 1.9200 5.595- 1.7664 - 7.744				
	537 (Adjusted R ts pats : Market Value : (J) Number (: 0) Coats : 6 Coats : 6 Coats : 6 Coats : 6 Coats : 8 Coats	of Coats	Muttiple Comp Maan Difference (0-J) -3.6975* -3.6975* -1.013 3.6975* -1.013 3.8188* 1.013	Std Error .7764 .7764 .7764 .7764 .7764 .7764	Sig. .0001 .0001 .0001 .0001 .9844 .0001	95% Confid Lower Pound - 5.954 - 7.166 - 7.0291 - 7.0291 - 7.768	nce Interval Upper Bound - 1.7894 - 1.9205 - 5.565- 1.7666 5.7166 - 2.029				
R Squared = . ost Hoc Tes umber of Cc Dependent Variable Tukey HSD ONumber of Coats @ Number of Coats @ Coats Based on observed	537 (Adjusted R ts pats Market Value Coals Coa	of Coats	Multiple Comp Mean Difference (-J) -3.6875* -3.8188* 2.6975* -1313 3.8188* .1313	Std Error .7764 .7764 .7764 .7764 .7764 .7764	Sig. .0001 .0001 .9844 .0001 .9844	95% Confid Lover Bound -5.716 1.7996 -2.0291 1.9209 -1.7868	nce Interval Upper Bount - 1.789 - 1.9200 5.5865 - 1.766 5.7166 2.0291				
	537 (Adjusted R ts bats : Market Value (J) Number (8 Coats 10 Coats 10 Coats 6 Coats 10 Coats 6 Coats 10 Coats 10 Coats 10 Coats 10 Coats 10 Coats 10 Coats	of Coats	Mean Difference (6-J) -3.6875* -3.8185* -3.8195* -3.8185* -3.8185* -3.8185* -3.8185* -3.8185*	Std. Error 7764 7764 7764 7764 7764 7764 7764	Sig. .0001 .0001 .0001 .9844 .0001 .9844	95% Confid -5.9654 -5.7166 -7.0291 1.9209 -1.7866	nce Interval Upper Bounc 1. 1990 5. 595- 1. 7566 5. 7166 2. 0291				
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	Adjusted R (Adjusted	Squared = . of Coats ant at the 0.	Mean Multiple Comp (-3, 0075° -3, 0075° -3, 0075° -1, 013 3, 0075° -1, 013 3, 0075° -1, 013 3, 0168° -1, 013 3, 0168° -1, 013 3, 0168° -1, 013 3, 0168° -1, 013 3, 0168° -1, 013 3, 0168° -1, 015 3, 015 5, 0	Std Error 7764 7764 7764 7764	Sig. .0001 .0001 .0001 .0001 .0001 .9844	95% Confid Lower Bound -5.7166 1.7196 -2.0291 1.9209 -1.7868	nce Interval Upper Bourno - 1.7694 - 1.9206 - 5.9766 - 5.7166 - 2.0291				
	327 (Adjusted R ts bats Market Value (J) Number 8 Coats 8 Coats 9 Coats 9 Coats 9 Coats 8 Coats 8 Coats 9 Coats 8 Coat	Squared = . of Coats ant at the 0.	Mean Difference (3) -3.6975* -3.8188* .1313 3.8188* .1313 05 level.	Sid. Error 7764 7764 7764 7764 7764 7764	Sig. .0001 .0001 .9044 .9844 .9844	95% Confid Lower Bound -5.7166 1.7096 -2.0291 1.9209 -1.7866	nce Interval Upper Bounc 1.7694 1.9200 5.595- 1.7696 5.7166 5.7166 5.7166				
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	Adjusted R (Adjusted	Squared = . of Coats and of the 0. Subby 1 73.1063	Mean Difference (5) -3.6875* -3.8188* .1313 3.8188* .1313 05 level.	Sid. Error 7764 7764 7764 7764 7764 7764	Sig_ .0001 .9044 .0001 .9844	95% Confid Lower Bound - 5,854 1,7066 - 2,0291 1,9209 - 1,7866	nce interval Upper Bours 1.7694 1.9206 5.5716 5.7164 2.0291				
	Adjusted R (Adjusted	Squared = . of Coats ant of the 0. Subo 1 1 72.1063	Mean Mean Difference 0.6275* - 2.8198* 2.6875* - 3.8198* 3.8188* -1313 3.8188* .133 05 level.	Sid Error 	Sig. .0001 .0001 .0004 .0004 .0004 .0004 .0004	95% Confid Lower Bound - 5 9854 - 7 986 - 2 0291 - 1 7866	nce Interval Upper Bound 1, 789 1, 9200 5, 505 5, 7166 2, 0291				
	327 (Adjusted R ts bats Market Value (J) Number (0 Coats 0	Squared = . of Coats art1 at the 0. S 1 1,0000	526) Multiple Comp 0-3 -3.6875* -3.61875* -3.6188* 1313 05 level. et 2 76.7938 76.9250 .9844	Sid. Error 7764 7764 7764 7764	Sig .0001 .0001 .9844 .0001 .9844	95% Confid Lower Bound -5.7166 1.7096 -2.0291 1.9209 -1.7868	nce Interval Upper Bounc - 1, 7694 - 1, 9704 5, 565 - 1, 7666 - 5, 7166 - 2, 0291				
	27 (Adjusted R ts hats Market Value (A) Number (C) Number (C	Squared = . of Coats 1 1 1.0000	Multiple Comp Mean Difference 0-3 -3.6875* -3.6875* -1313 3.8185* 3.8195* 1313 05 level. 2 76.7938 76.9250 .984	Std. Error 7764 7764 7764 7764 7764 7764	Sig. .0001 .0001 .9044 .9044	95% Confid Lower Bound - 5,854 1,7966 - 2,0291 1,9209 - 1,7666	nce Interval Upper Bound 1,789 5,595 5,716 5,716 2,029				
	Adjusted R (Adjusted	Squared =	Moan Differince -3.8975* -3.8185* -3.8188* -3.313 05 level.	Sid Error .7764 .7764 .7764 .7764 .7764 .7764	Sig .0001 .0001 .9044 .9844	95% Confid - 5 5054 - 5 7166 - 7 0291 - 2 0291 - 1 7866	nce Interval Upper Bound - 1, 799 - 1, 9200 - 5, 955 - 1, 7660 - 5, 7166 - 2, 0291				
	Adjusted R (Adjusted	Squared = . of Coats ant at the 0. S Subsets are 9 = 4.823. Subsets are 9 = 4.823. Subsets are 9 = 4.823. Subsets are 9 = 8.829. 1 = 10000000000000000000000000000000000	Moan Difference 0-3 -3.6189* -3.8188* -3.8188* -3.313 05 level. et 2 76.9250 -824 -384 -384	Std. Error 7764 7764 7764 7764 7764	Sig. .0001 .0001 .0001 .0001 .0001 .0001 .0001 .0001	95% Confid Lower Bound -5.7166 1.7996 -2.0291 1.9209 -1.7866	nce Interval Upper Bound - 1, 759 - 1, 970 5, 595 - 1, 766 5, 716 2, 0291				
	Adjusted R (Adjusted	Squared =	Multiple Comp Minun 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	Std Error 7764 7764 7764 7764 7764 7764 7764	Sig .0001 .0001 .9044 .0001 .9844	95% Confid Lower Bound - 5,864 - 7,166 - 7,066 - 2,0291 - 1,7866	nce Interval Upper Bound 1,789 5,565 5,716 5,716 2,029				



Multiple Comparis



6. Since the lines of the profile plot (below) each follow the same basic pattern with no substantial crossings, we conclude that there are probably no significant interaction effects.



- 7. Levene's Test for Homogeneity of Variances and Normal Q-Q Plots.
 - **Step 0:** Check Assumptions of Equal Variances (Homogeneity of Variances) and Normality The Levene Statistic *p*-value = 0.8909 is greater than α = 0.05 (from Step 2), so we fail to reject the null hypothesis that the variances are all equal. Since the points in each plot appear to closely follow the respective diagonal lines, then the populations are approximately normally distributed. Since the variances appear to be equal and the groups seem to be normally distributed (and we have random/independent samples), we may continue with ANOVA.



8. You should use the output information in the following manner to answer the question.

Despite thinking that there are no significant interactions (based on profile plot), we must still formally test for significant interaction between the two factors.

Test for significant interaction effects:

	H_0 : There is no interaction between number of coats and batches. H_a : There is an interaction between number of coats and batches.							
<u>Step 2</u> :	Significance Level $\alpha = 0.05$							
<u>Step 3</u> :	Critical Value(s) and Rejection Region(s) Reject the null hypothesis if p -value ≤ 0.05 .							
<u>Step 4</u> :	Construct the	ANOV	A Table				-	
		Tests	of Between-Su	ojects Effects				
	Dependent Variable:	Market Value						
	Source	Чf	Type III Sum of Squares	Mean Square	F	Sia		
	factor_A	2	150.3879	75.1940	15.5910	.00001327		
	factor_B	3	152.8517	50.9506	10.5643	00003984		
	factor_A * factor_B	6	1.8521	.3087	.0640	.99882834	k	
	Error	36	173.6250	4.8229	****	••••	(
	Corrected Total	47	478.7167					
Ston 5:	From the output p -value = Sig.	ut, <i>F_{AB}</i> = = 0.998	0.0640 w 82834	ith 6 and 3	6 degre	es of free	adom.	
<u>Step 5</u> .	Conclusion			<u>-</u>	<i>.</i>			
	Since <i>p</i> -value :	= 0.9988	32834 > 0	$.05 = \alpha$, we	e tail to r	eject the	null nypoth	esis.

Step 6: State conclusion in words

At the α = 0.05 significance level, there is not enough evidence to conclude that number of coats and batches have a significant interaction effect on mean value of the imitation pearls.

Since there are no significant interaction effects, we shall test for effects (differences in means) due to the individual factors.

Test for factor A differences:

Step 1:	Hypotheses
	$H_0: \ \mu_{A1} = \mu_{A2} = \mu_{A3}$
	H_a : at least one mean differs from the rest
<u>Step 2</u> :	Significance Level
	$\alpha = 0.05$
<u>Step 3</u> :	Critical Value(s) and Rejection Region(s)
	Reject the null hypothesis if <i>p</i> -value ≤ 0.05 .
Step 4:	Construct the ANOVA Table

Tests of Between-Subjects Effect

rests of Detween-Subjects Effects								
Dependent Variable: Market Value								
		Type III Sum						
Source	df	of Squares	Mean Square	5 • • •	• • Sig. •			
factor_A	2	150.3879	75.1940	15.5910	.00001327			
factor_B	3	152.8517	50.9506	10.5843	.90003984			
factor_A * factor_B	6	1.8521	.3087	.0640	.99882834			
Error	36	173.6250	4.8229					
Corrected Total	47	478.7167						

From the output, $F_A = 15.5910$ with 2 and 36 degrees of freedom. *p*-value = Sig. = 0.00001327

Step 5: Conclusion

Since *p*-value = $0.00001327 \le 0.05 = \alpha$, we shall reject the null hypothesis.

Step 6: State conclusion in words

At the α = 0.05 significance level, there is enough evidence to conclude that there are differences in mean value of the imitation pearls among the numbers of coats.

Test for factor B differences:

<u>Step 1</u> :	Hypotheses	Hypotheses							
	$H_0: \ \mu_{B1} = \mu_{B2} = \mu_{B3} = \mu_{B4}$								
	H_a : at least one mean differs from the rest								
<u>Step 2</u> :	Significance	Significance Level							
	$\alpha = 0.05$								
<u>Step 3</u> :	Critical Value	Critical Value(s) and Rejection Region(s)							
-	Reject the null hypothesis if p-value ≤ 0.05 .								
Step 4:	Construct the ANOVA Table								
	Tests of Between-Subjects Effects								
	Dependent Variable: Market Value								
			Type III Sum						
	Source	df	of Squares	Mean Square	F	Sig.			
	factor_A	2	150.3879	75.1940	15 5810	.00004327			
	factor_B	3	152.8517	50.9506	10.5643	.00003984			
	factor_A * factor_B	6	1.8521	.3087	.0640	99882834			

From the output, $F_B = 10.5643$ with 3 and 36 degrees of freedom.

173.6250

478.7167

p-value = Sig. = 0.00003984

36

47

Step 5: Conclusion

Error

Corrected Total

Since *p*-value = $0.00003984 \le 0.05 = \alpha$, we shall reject the null hypothesis.

4.8229

Step 6: State conclusion in words

At the α = 0.05 significance level, there is enough evidence to conclude that there are differences in mean value of the imitation pearls among the batches.

9. Since differences were found in the numbers of coats, we should perform a Tukey-Kramer (Tukey's W) multiple comparison analysis to determine which of the numbers of coats is best. Using the previous output, here is how such an analysis might appear.

Multiple Comparisons							
Dependent Variable:	Market Value						
Tukey HSD							
		Mean Difference			95% Confidence Interval		
(I) Number of Coats	(J) Number of Coats	(I-J)	Std. Error	Sig.	Lower Bound	Upper Bound	
6 Coats	8 Coats	-3.6875*	.7764	.0001	-5.5854	-1.7896	
	10 Coats	-3.8188*	.7764	.0001	-5.7166	-1.9209	
8 Coats	6 Coats	3.6875*	.7764	.0001	1.7896	5.5854	
	10 Coats	1313	.7764	.9844	-2.0291	1.7666	
10 Coats	6 Coats	3.8188*	.7764	.0001	1.9209	5.7166	
	8 Coats	.1313	.7764	.9844	-1.7666	2.0291	
Based on observed n	neans.						
*. The mean differ	ence is significant at the	0.05 level.					

Thus, we are 95% confident that 6 coats yields a different (smaller) mean value of the imitation pearls from that when using 8 or 10 coats (these two mean values are similar).



This table corresponds to our "underline diagram". Note that using 8 or 10 coats (since they are similar) will yield the largest mean value of the pearls.

Since differences were found in the batches, we should perform a Tukey-Kramer (Tukey's W) multiple comparison analysis to determine which of the batches is best. Using the previous output, here is how such an analysis might appear.

Denender	t Variabla: M	larket Value				
Tukey HO	n vanabie. w	laiket value				
Tukey Hol	5					
		Mean Difference			95% Confidence Interval	
(I) Batch	(J) Batch	(I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Batch 1	Batch 2	-2.7083*	.8966	.0229	-5.1230	2937
	Batch 3	-3.4250*	.8966	.0027	-5.8396	-1.0104
	Batch 4	.8333	.8966	.7893	-1.5813	3.2480
Batch 2	Batch 1	2.7083*	.8966	.0229	.2937	5.1230
	Batch 3	7167	.8966	.8542	-3.1313	1.6980
	Batch 4	3.5417*	.8966	.0019	1.1270	5.9563
Batch 3	Batch 1	3.4250*	.8966	.0027	1.0104	5.8396
	Batch 2	.7167	.8966	.8542	-1.6980	3.1313
	Batch 4	4.2583*	.8966	.0002	1.8437	6.6730
Batch 4	Batch 1	8333	.8966	.7893	-3.2480	1.5813
	Batch 2	-3.5417*	.8966	.0019	-5.9563	-1.1270
	Batch 3	-4.2583*	.8966	.0002	-6.6730	-1.8437
Based on	observed m	eans.				

Thus, we are 95% confident that batches 4 and 1 (similar mean values) yield a different (smaller) mean value of the imitation pearls from that when using batches 2 or 3 (similar mean values).



This table corresponds to our "underline diagram". Note that batch method 2 or 3 (since they are similar) will yield the largest mean value of the pearls.